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Factors Related to Successful Completion of Developmental Mathematics Courses

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FACTORS RELATED TO SUCCESSFUL COMPLETION OF
DEVELOPMENTAL MATHEMATICS COURSES

for

Jason Bagley

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Approved:

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ABSTRACT

Factors Related to Successful Completion of

Developmental Mathematics Courses

by

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Dweck's mindset, math anxiety, multiplication skills, and attitudes toward mathematics were measured and used to predict student success in developmental math courses as measured by percent of points earned and pass rates. A pre/post survey design research study was conducted with students in Math 990, Math 1010, and Math 1050 at Utah State University. Data were analyzed using linear regression to predict percent of points earned and logistic regression to predict pass rates.

Math anxiety was found to have a large and statistically significant negative effect on student course grades and pass rates. Dweck's mindset was found to be a strong predictor of student success. Multiplication skills were related to student success as measured in percent of points earned in the course, particularly in beginning algebra courses. Students' attitudes toward mathematics, particularly perceived ability and interest in mathematics, predicted very large

differences in student achievement and pass rates.

The data supported claims that anxiety impacts students' ability to do mathematics and achieve. Dweck's research on mindset and previous research was also supported through the analyses performed. Evidence supports previously made attempts at interventions targeted toward student anxiety and changing students' mindset, as noted by Hattie and Dweck.

PUBLIC ABSTRACT

Factors Related to Successful Completion of

Developmental Mathematics Courses

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The goal of this research was to identify factors that contribute to students' achievement in developmental math courses. This research collected information on several factors which have been suggested to have an effect on student achievement, particularly in developmental math courses at Utah State University, and analyzed their effects on student achievement. The literature review identified several factors that appeared related to student achievement, but many of these studies only analyzed a few factors. Very few studies have tried to analyze multiple variables together to try and identify which factors contribute most to student achievement and which observations can be better explained by other variables.

The data collected from this research provides a great amount of information, with nearly 2000 observations, and several variables. While this data may not be representative of all students, it does provide information that may be relevant to many groups. This research provided supporting evidence to Dweck's theory of Mindset, that students learn best when they believe they are can learn. Anxiety was found to have one of the largest effects on student achievement.

The costs for this study were very minimal. For each class surveyed, twenty minutes was spent giving a pre test near the beginning of the semester and another twenty minutes was spent giving a post test near the end of the semester. Other costs included copying, data entry, and time spent analyzing data.

ACKNOWLEDGMENTS

I would like to thank the Utah State University Math Department for graciously allowing myself and Dr. Callow-Heusser permission to conduct the research study that this thesis is based on. Significant knowledge has been gained and research will continue for some time to come on the effects of variables recorded and studied herein. This rewarding experience would not have come without their support.

I would like to thank the course instructors and course supervisors who were willing to sacrifice time for this study and opened the way to make this possible. Each one was patient as we visited and was so willing to help in collecting the data from students on both occasions.

Above all, I express the greatest appreciation to Dr. Catherine Callow-Heusser, who guided me in this process and the research. Although she was very busy with many other research grants and educational pursuits, she guided me to this final conclusion and provided the necessary feedback to finish this thesis. The prompt completeness of this thesis would not have resulted if not for her insistence to push myself and work harder, especially near the end when the deadlines loomed overhead.

Jason Bagley

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PROBLEM STATEMENT

Success in developmental mathematics is a key goal, particularly for increasing Science, Technology, Engineering, and Mathematics (STEM) participation in the US. Yet, developmental math courses are among the most failed college courses at Utah State University (Cutler, 2009) and elsewhere (Twigg, 2007). Research provides evidence that student success is influenced by students' preparation, course-study habits (including attendance, class participation, homework completion, etc.), math-related anxiety, and attitudes towards mathematics. However, recent research from Dweck (2008) and others has also shown that what she terms to be a "growth mindset" is another important factor for academic success and, in particular, successful completion of developmental math courses. Her research also demonstrated that this mindset can be taught and learned.

Unfortunately, much of this research has involved groups with demographics different than our students at Utah State University. To increase pass and retention rates in developmental math courses, it is important to know more about factors that influence success, including mindset.

I proposed to investigate the effect of these factors, particularly growth mindset, math-related anxiety, and students' attitudes towards mathematics, on student success in algebra level math courses taught at Utah State University and to identify relationships between these factors. Universities could use this evidence to make formative adjustments to developmental math courses and student support services to improve student success, particularly if the findings provided additional support for recommendations from Dweck's research.

RESEARCH QUESTIONS

Is mindset a good predictor of student outcomes in developmental math courses as measured by overall course grades, scores on exams and/or successful completion of courses?

To what extent are gender, prior math preparation (as measured by multiplication skills, years since prior math class, and highest level of math previously attained), course-study habits (homework completion), experiences since high school (religious mission, military service, raising a family, etc.), math-related anxiety, and attitudes towards mathematics related to students' grades and course completion (including pass, fail, and drop rates) in developmental math courses at Utah State University?

LITERATURE REVIEW

Developmental Math Failure, Withdrawal, and Retake Rates

Twigg (2007) from the National Center for Academic Transformation stated that typical drop-fail-withdrawal (commonly called DFW) rates were between 40% and 50% for all developmental courses including math, English, and other courses. At Utah State University (USU), DFW rates in developmental math courses ranged between 10% and 45% between Fall 2005 and Spring 2009 semesters. Math 900 (Beginning Algebra, now called Math 990 at USU), Math 1010 (Intermediate Algebra), and Math 1050 (College Algebra) averaged 34.7%, 31.2%, and 17.0% respectively. After the implementation of the new placement exam in 2007, Math 900 averaged a DFW rate of 38.8%, which was a statistically significant increase (Cutler, 2009).

Student Prior Preparation

With an effect size of .67, a meta-analysis by Hattie (2009) indicated students' prior achievement is a strong indicator of current achievement in science and math courses. Prior achievement predicted success for students as they transitioned between high school and college or university (Kuncel, Hezlett & Ones, 2001), or as students graduated and sought success in their job vocations (Roth, BeVier, Switzer, & Schippmann, 1996). Some research suggested prior achievement is one of the best individual predictors for academic success (Schuler, Funke, and Baron-Boldt, 1990).

One potential indicator of students' preparation is multiplication facts fluency. Callow-Heusser (2014) showed that multiplication facts fluency for students entering Math 990 was low, as data from this study confirms, as shown in Figure 1.

Figure 1 shows the number of multiplication facts Math 990 students answered correctly within one minute at the beginning of the semester. The Common Core State Standards for Mathematics state the following (italics added, http://www.corestandards.org/Math/Content/3/OA/),

> "Fluently multiply and divide within 100, using strategies such as the relationship between multiplication and division (e.g., knowing that $8 \times 5 = 40$, one knows $40 \div 5 = 8$) or properties of operations. *By the end of Grade 3, know from memory all products of two one-digit numbers.*"

Without multiplication fact fluency, in which students recall quickly, accurately, and confidently the result of single digit multiplication, they are likely to struggle with new concepts because success with simple multiplication disrupts problem-solving and uses cognitive processes needed for understanding more complex concepts. Much like needing to know which sound the letter "a" makes while reading the words cat, make, and tall before one can read fluently, students need to be able to quickly recall multiplication facts, for example, to calculate equivalent fractions or identify factors of integers—both building blocks for algebraic operations. Cognitive psychologists have long argued that higher-level aspects of skills require that lower level skills be developed to automaticity. In fact, Grover Whitehurst, then Director of the Institute for Educational Sciences (IES), stated: "Cognitive psychologists have discovered that humans have fixed limits on the attention and memory that can be used to solve problems. One way around these limits is to have certain components of a task become so routine and over-learned that they become automatic" (Whitehurst, 2003). To investigate this claim, Price, Mazzocco, and Ansari (2013) conducted research using brain imaging

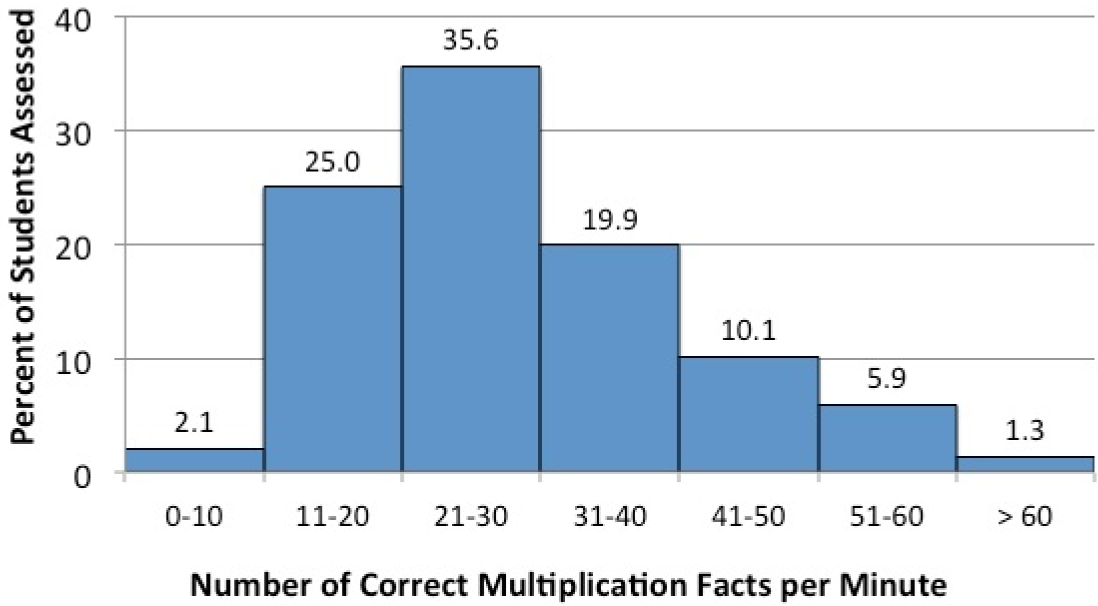

Figure 1: Distribution of Math Skills for Students Involved in Study

and concluded that brain activation during single digit arithmetic predicted high school math scores. Therefore, while research-based recommendations for multiplication fluency vary, basic math facts are building blocks for math that form a foundation needed for later learning and application of math concepts.

Some research recommends that students be able to correctly write answers to 30-40 multiplication facts per minute with 95% accuracy (Crawford, 2014). As shown in Figure 1, nearly 53% of students in Math 990 were below 30 correct facts per minute, and more than 58% of students exceeded error rates of 5%.

Course-Study Habits

Study habits are likely good predictors of college success. One meta-analysis, which tested the effect of homework versus no-homework treatments from twenty studies, found an average effect size of $d = .21$ in favor of assigning homework (Cooper, 1989).

Math Anxiety

Studies of the brain have shown that when students with math anxiety perform mathematical calculations that the right amygdala regions, which are important for processing negative emotions, become hyperactive. With this increased activity, there was an accompanied reduction in activity in regions of the brain that support working memory and numerical processing, namely the dorsolateral prefrontal cortex and posterior parietal lobe (Maloney & Beilock, 2012). Given this research, we expected math anxiety to have an effect on achievement.

Anxiety in any form has been shown to be very debilitating when it is overwhelming or excessive (Achor, Crum, & Salovey, 2013). Roughly 18% of the United States population has an anxiety-related disorder, which is also the most common type of mental disorder (Anxiety and Depression Association of America, 2014). In connection to mathematics anxiety, Hattie (2009) noted,

> "The subject of mathematics in particular promotes expression of anxiety that take such forms as tension and dislike (attitudinal features); worry, helplessness, and mental disorganization (cognitive features); and fear (emotional feature)."

Hattie (2009) also reported that reducing anxiety had an effect size of $d = .40$ on student achievement.

Student's anxiety towards mathematics can be learned from others, such as teachers, or form as a result of previous experience. For example, Maloney and Beilock (2012) found a relationship between teachers who have math anxiety and resulting math anxiety in the teachers' students.

Math Attitudes

Students' attitudes have also shown to affect mathematics achievement with small to moderate effect sizes. Hattie (2009) reported an effect size of $d = 0.36$ and an association effect size of $r = .12$ was found in another meta-analysis (Kishor & Ma, 1997).

Kishor and Ma (1997) also analyzed 5 studies which explored a causal relationship between attitudes and achievement (instead of an observed relationship). In this meta-analysis, the researchers found that attitudes had a causal effect of only $r = .08$ on achievement. Achievement was found to have a causal effect of $r = .00$ on attitudes, meaning that students' achievement does not appear to change their attitudes toward mathematics. However, Kishor and Ma suggested that these results were probably due to ineffective measurement tools which were used in the studies, but they do provide some evidence that there may be little to no causal relationship between achievement and attitudes.

Growth Mindset

Dweck (2008) identified two types of mindsets that play a key role in math achievement. As Dweck summarized in publications describing her research,

> "Students who believe that intelligence or math and science ability is simply a fixed trait (a fixed mindset) are at a significant disadvantage compared to students who believe that their abilities can be developed (a growth mindset)."

Blackwell, Trzesniewski, and Dweck (2007) followed 373 students with equal prior math achievement as they transitioned to 7th grade. They tested their mindsets and found that the grade differences between those with a growth mindset and a fixed mindset diverged over the next two years. The grade difference appeared as early as the first semester in 7th grade and continued. Those with a growth mindset showed a grade increase over the next two years while those with a fixed mindset stayed at about the same level and decreased on average.

A similar study was conducted with college students who took a pre-med organic chemistry course (Dweck, 2008). Students' mindset was a good predictor of students' success in the course. Further, if students with a fixed mindset received a poor grade early on in the course, they were much less likely to recover and succeed as students with a growth mindset who had similar experiences.

Dweck (2008) also mentioned that mindset alone, while a good predictor of achievement, is not the only factor worth considering. She noted that even students with a fixed mindset can have high levels of achievement. A mindset is more accurately a predictor of students' responses to setbacks and failure. A student with a fixed mindset is more inclined to believe that their failure is out of their control and resort to negative strategies such as effort withdrawal and cheating, while a student with a growth mindset is more inclined to employ positive strategies such as putting forth more effort and employing new strategies for learning.

Therefore, Dweck (2008) noted that in most of these studies, students with a fixed mindset who did not encounter difficulties performed almost equal to their peers, while those who encountered challenges or obstacles did not achieve as much as their growth mindset counterparts.

Given the reputation of developmental math courses among students and the high dropout and failure rates, these courses likely serve as an obstacle to continuing college. As some students transition from high school to college mathematics, they may encounter new setbacks. This may make mindset a good predictor for drop, fail, and withdrawal rates, suggesting that more research is needed to determine whether students exhibiting a fixed mindset in math courses create barriers to their success.

Dweck (2008) also stated that concepts of fixed intelligence compared with a growth mindset seem to depend on the subject of study. Students appear more likely to view their math intelligence as fixed even if they display a growth mindset in other subjects. Since we were studying developmental math courses, which were among the most failed courses at Utah State University, we hypothesized that many students could have a fixed mindset toward mathematics and, therefore, struggled because of previous failures in taking math courses.

Influences from Religion

Jeynes (1999, 2002, 2003, 2010) researched the effects of religion on student success, particularly in relation to minority groups such as African Americans and Hispanic students. He found that students from these ethnic groups performed as well as Caucasians when students had a high level of religious involvement. In fact, in several studies, he found that the achievement gap between black and white students disappeared for black students with high levels of religious involvement.

Utah has a high concentration of Christians who belong to the Church of Jesus Christ of Latter-day Saints (LDS). Canham (2012) estimated that 62.2% of the residents in Utah were LDS using data from the census and local data from the LDS church. The estimated concentrations of LDS members were published for several counties. Cache county was not explicitly listed, but it is close in proximity to Box Elder county which was listed with 77.2% LDS.

Men over the age of 18 from the LDS church are encouraged to serve a 2-year proselyting mission, and an 18-month proselyting mission was also available for women over the age of 19. Almost 2 years ago, these ages were decreased from their previous requirements of 19 and 21 respectively, and many students at USU left at earlier ages to serve LDS missions. Some of these students, and others who were already serving missions at that time, returned during the 2014-2015 school year. Given Jeynes' (2003) implications, students' participation in a mission may impact their attitudes, mindset, and overall achievement. Post secondary experiences, such as religious service or staying home to raise children given religious beliefs, may also account for variability in outcomes of developmental math courses or mindsets.

METHODS

Research Design

This pre/post survey design study included a survey and an assessment administered to students in Math 990 (Beginning Algebra), Math 1010 (Intermediate Algebra), and Math 1050 (College Algebra) courses at Utah State University. The administration of the survey was followed by a one-minute timed multiplication math facts assessment in each section visited during the preliminary survey. During the post survey, the one-minute timed multiplication math facts assessment was given prior to students completing the survey.

Measures were administered by researchers and a few course instructors who were trained in appropriate administration and took approximately twenty minutes during a class period near the beginning of the semester and again near the end of the semester. Due to time constraints and the need to maximize instructional time, measures were administered during one class period for each class at the beginning and end of the semester.

Study Participants

Students in Math 990, Math 1010, and Math 1050 who attended on the day the survey was administered in their section and agreed to participate were included in this study. Students who were absent were unable to complete the measures. Students who chose not to participate were not required to participate.

Measures

For information on how the public data set was coded, see Table 24 in Appendix B.

Measurement items on pre and post surveys included four items on student preparedness, the Abbreviated Math Anxiety Scale (AMAS) (Hopko, 2003), an abbreviated version of Dweck's Mindset assessment (Dweck, 2006), an abbreviated version of Dartmouth Colleges' attitudes survey (Korey, 2000), and two items to measure students' perceived difficulty of the course (Sauro, 2009), adapted for use in this study.

In some Dweck's publications, it was proposed that students' mindset towards certain subjects may be more fixed than their general mindset. Given this claim, Dweck's Mindset assessment (2006) was changed to assess students' mindset toward mathematics. For example, one of Dweck's items states, "You can always substantially change how intelligent you are." The item was changed to "You can always substantially change how intelligent you are *in math*" (italicized words were bolded on the survey). Dweck (2008) described several studies in which Mindset survey items were adapted to be domain specific. Additionally, Scott and Ghinea (2013) similarly modified Dweck's Mindset items for the domain of programming and found these items had greater utility in predicting software development practice.

Since the design of this experiment, Dweck has modified her Mindset assessment. As a result, the questions and scoring methods used in this thesis and based on her previous publications differ slightly from her most current work (Dweck, 2015). However, in comparing her new scoring methods with the ones employed in this study, 5 students out of 1892 were categorized differently between the two methods. Because the data analysis was complete at the time we located Dweck's recent changes, our scoring methods were not changed to reflect Dweck's most recent scoring methods.

One item on the Abbreviated Math Anxiety Scale was adjusted to try and meet modern applications. The original item “Having to use the tables in the back of a math book” was changed to “Using a calculator to answer a complex problem.”

The original AMAS had nine items loaded into two factors by the researchers which they called Learning Math Anxiety (LMA) and Math Evaluation Anxiety (MEA). A factor analysis was performed with the data collected from our study, using the adjusted item, and the loadings were found to be the same and more statistically significant than those reported by Hopko et al (2003).

Anxiety was calculated as the average of the values given by students to the AMAS items (using only those answered by the student). In a similar manner, summary scores were calculated for LMA and MEA using the AMAS items designated by Hopko et al (2003).

There were four factors analyzed from Dartmouth’s attitudes survey. The Ability factor measured students’ evaluation of their ability to perform math calculations correctly. Interest was a measurement of students’ interest in learning mathematics (particularly the variety and depth). Personal Growth measured whether students believe learning math will help them to grow and improve in connection to other major skills (e.g. “Doing math helps me understand myself”). The last factor, Utility, measured students’ perception that math is useful for them in their future career and everyday use. A few items that were not scored by those who designed the Dartmouth College attitudes survey were removed from our surveys to maximize time spent on instruction after survey administration.

The one-minute timed multiplication facts assessment used was taken from free teacher resources printed from rocketmath.com, originally published in 2013. The file link was titled “Multiplication 2-minute timings and answers” and was located at http://www.rocketmath.com/p/free-downloads.html, obtained 30 May

2015. Form 5 was used for our assessment, and the time was changed to one-minute for this study. The file was not included herein.

For each course, there was one small section (each containing between 9 and 15 students depending on the course) funded through Student Support Services in which only students with disabilities and first generation college students were allowed to enroll. This section, for each course, was configured differently than all other sections in terms of homework and number of exams, and as such was not singled out in analyses so as to not identify individual students.

During the Fall 2014 semester, there were many difficulties experienced with a transition from a previous version of WileyPlus online homework system to their new version, which could not be resolved quickly. A few weeks into the semester, the instructor over the large lecture courses decided the use of the online homework system would be eliminated for students in the large lecture courses. No replacement homework assessment was introduced into the class. As a result, the instructor decided to give all students full credit for all homework assignments that would have been required during the semester. This gave every student who was enrolled in the large lecture courses a minimum of 15% of total points earned without any participation.

In an effort to try and gain a better picture of what impact our predictors may have had on students' actual achievement, an adjusted Math 1050 percent of points completed (denoted as the course Math 1050A) was created for students in the large lecture sections. This adjustment removed the 15% awarded in lieu of homework to every student and scaled the remaining points to 100%. The adjustment assumed that students would have earned as many points from homework as they earned from exams and quizzes (being weighted by their relative value).

Data Analysis

Descriptive statistics were calculated for variables of interest, such as number of students who passed, failed, withdrew, or dropped from each section.

Correlations were calculated between percent of points earned and predictor variables, such as Dartmouth attitude factors, and anxiety factors.

All analyses predicting percent of course points earned or exam scores using predictor variables were performed using linear regression on summary data. No transformations of outcome or predictors were performed as part of these analyses. Assumptions of normality were not verified.

R-square values were calculated for statistically significant variables in each course to give a comparative measure of their ability to predict the percent of points earned in each course. Partial R-square values were also calculated to estimate what percent of the unexplained variability in the percent of points earned could be explained by adding more predictor variables.

All analyses predicting pass rates using predictor variables were performed using logistic regression. In each case, the outcome variable was a binary variable (whether a student passed) and no transformations of predictors were performed as part of these analyses. Assumptions of normality were not verified.

RESULTS

Scale Reliability

Cronbach's alpha measure of internal reliability was calculated for related survey items. As shown in Table 1, the data provided evidence that the proportion of variability in item-level scores that was the result of differences between participants was high (i.e., .70 or above) for most scales. In fact, data for most scales demonstrate very high reliability with Cronbach alpha statistics greater than .80. Cronbach's alpha for the four enjoyment and preparedness of school and math items was slightly lower than .70 at .66, and Cronbach's alpha for the math attitudes subscale of personal growth was moderate at .56, indicating that the

Table 1

Cronbach's Alpha Measure of Internal Reliability

		Beginning of Semester		End of Semester	
Scale	Number of Items	Sample Size	Cronbach's Alpha	Sample Size	Cronbach's Alpha
Enjoyment/Preparedness	4	1893	.66	1413	.67
Math Anxiety (All Items)	9	1865	.87	1391	.88
Math Evaluation	4	1884	.85	1403	.84
Learning Math	5	1876	.82	1400	.82
Mindset (All Items)	8	1841	.84	1381	.84
Math	4	1871	.84	1398	.85
General	4	1862	.74	1395	.73
Math Attitudes (All Items)	30	1845	.90	1359	.89
Personal Growth	4	1890	.56	1401	.58
Ability	6	1879	.85	1398	.84
Utility	3	1895	.80	1403	.80
Interest	4	1886	.84	1400	.84

relationship between items was not as strong. Note that some math attitudes items were not used in the four subscales, such that the total number of items used for the subscales was less than the total number of math attitudes items (Korey, 2000).

Pass, Drop, Fail, and Withdrawal Rates

Table 2 summarizes the observed drop rates in Math 990, Math 1010, and Math 1050. The table also summarizes drop rates for the adjusted Math 1050 scores as indicated. Please note that withdrawal and drop rates were unaffected by the changes in final grades.

An observed pass rate of 62.65% was observed for Math 990, and a similar pass rate of 62.92% was observed for Math 1010. However, a much larger pass rate of 86.39% was observed for students in Math 1050. After the adjustment for students in the large lecture sections who completed Math 1050, a pass rate of 79.38% was observed.

Attrition

Differences between students who completed the course (passed or failed) and those who did not complete the course (withdraw or drop) were computed and tested for significance. Unless otherwise noted herein, differences observed between the two groups were not found to be statistically significant at $\alpha = .05$.

Categorical variables were also tested for attrition. However, in Math 990 and Math 1050 cell counts were too small to make a Chi-square test appropriate. In Math 1010, some cell counts were less than five, but no cell counts were zero. As such, the results of the attrition analysis for the three categorical variables will be reported for Math 1010, but will not be provided for Math 990 or Math 1050.

Table 2

Summary of DWF Counts and Rates

Class	Pass	Fail	Withdraw	Drop	Total	Pass Rate
Math 990	265	135	14	9	423	62.65%
Math 1010	672	347	35	14	1068	62.92%
Math 1050	641	69	20	12	742	86.39%
Math 1050A	589	121	20	12	742	79.38%

1050A represented the adjusted scores for students in Math 1050.

In Math 990, students who completed the course appeared to differ from students who did not in the following continuous variables:

- Age
- Anxiety
- Multiplication facts incorrect
- Years since prior math course
- Time spent at home raising a family between high school and college
- Total time in breaks in education between high school and college

Students who completed the course were, on average, younger, had a lower anxiety rating, had spent less time at home raising a family and less total time spent away from school between high school and college, had fewer years since their prior math course, and made fewer mistakes on the one-minute timed multiplication facts assessment.

In Math 1010, students differed in the following continuous variables:

- Age
- Anxiety
- Learning Math Anxiety

- Math Evaluation Anxiety
- Dartmouth Ability factor
- Dartmouth Interest factor

Students who completed the course were, on average, younger, rated lower in each of the anxiety factors, and rated their ability and interest in math higher than students who did not complete the course.

Among those who completed, fewer students had a Fixed mindset and more students had a Growth mindset than would be predicted by independence. There were almost as many students with a Neutral mindset who completed as the analysis would expect. Students who completed were less likely to have a Growth math mindset than students who did not complete the course. The number of students with a Neutral mindset that completed was very close to what was expected (within rounding error). Students who completed the course appeared less likely to have taken Math 1050 or equivalent prior to enrollment in Math 1010 than students who did not complete the course, and also more likely to have taken Math 990 or equivalent before enrolling. Students in both groups appeared to be very similar in the proportion that had taken Math 1010, a level 1000 stats course, or calculus prior to enrollment.

In Math 1050, students who completed the course differed from students who did not in the following continuous variables:

- Age
- Anxiety
- Learning Math Anxiety
- Math Evaluation Anxiety
- Dartmouth Ability factor

- Dartmouth Interest factor
- Time spent at home raising a family between high school and college
- Time spent working between high school and college
- Total time in breaks in education between high school and college

Students who completed the course were, on average, younger, rated lower in each of the anxiety factors, had a higher ability and interest in mathematics, had spent less time at home raising a family between high school and college, had spent less time working between high school and college, and had spent less total time in breaks in education between high school and college than students who did not complete the course.

Relationship between Mindset and Outcomes

All models were analyzed using linear regression with Mindset as the only predictor. In each model, those with a Fixed mindset were considered the baseline group. Under the subsection "Successful Completion of Courses," logistic regression models were used to predict students' probability of passing, using mindset with "Fixed" as the baseline group.

The effects are summarized in tables located in Appendix C.

Percent of Points Earned

By comparing all regression models and the coefficients for Growth mindset in Table 3, the Growth coefficient was positive for every predicted model. While the Growth coefficients were not always statistically significant, the analysis indicated that those with a Growth mindset performed, on average, better than their Fixed mindset counterparts in these math courses.

Table 3

Predicting Percent of Points Earned with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	65.11***	4.91	7.17*	.041
	1010	62.96***	7.99**	11.59***	$< .001$
	1050	79.55***	2.45	3.60*	.057
	1050A	76.47***	2.83	3.95*	.080
Math	990	65.45***	9.44*	6.53*	.027
	1010	68.54***	−3.41	6.15***	$< .001$
	1050	79.82***	−3.22	3.77*	$< .001$
	1050A	76.48***	−2.93	4.44*	$< .001$

1050A represented the adjusted scores for students in Math 1050.
*$p < .05$, ***$p < .001$.

The effect sizes for the Growth coefficients (compared against those with a Fixed mindset) are all statistically significant with $p < .05$. When including all three mindsets in the comparison, the analysis showed differences exist among the three mindsets for each course, each with a reported p-value less than .10.

In Math 1010, a student with a Growth mindset was predicted to have 11.59 percent of points earned for the course higher than a student with a Fixed mindset, which was more than a full letter-grade difference. In Math 990, the predicted difference was 7.17% of points. In Math 1050, the differences were smaller at 3.60% of points.

As mentioned before, the concept of “Math Mindset” was used as suggested by Dweck (2008) to measure students’ mindset toward mathematics. In using this assessment, the regression models all resulted in a positive coefficient for Growth math mindset, though the coefficient was not always statistically significant. However, in Math 1010, Math 1050, and Math 1050A, a student with a Neutral math mindset was predicted to have a lower percent of points earned than a student with a Fixed math mindset according to the regression models, though the coefficients were not statistically significant. The only exception was in Math 990, where the regression coefficient for a student with a Neutral math mindset was higher than for a student with a Growth math mindset and the effect was statistically significant.

Scores on Exams

Grade differences predicted by mindsets were largest and most statistically significant in percent of points earned than those predicted for any individual exam. This was probably because of the cumulative effect of grade differences between those with differing mindsets that occur on every exam resulting in larger observable and statistically significant differences on students' final scores.

For Exam 1, which is shown in detail in Table 4, mindset appeared to be statistically significant only for Math 1010, both for Dweck's mindset and math mindset. Differences in mindset from the first exam are not apparent in Math 990

Table 4

Predicting Exam 1 with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	79.02***	.41	1.47	.717
	1010	73.53***	4.23*	8.78***	$< .001$
	1050	78.71***	1.86	2.07	.475
Math	990	79.47***	3.99	.57	.394
	1010	77.00***	−4.59*	5.66***	$< .001$
	1050	78.27***	−.68	2.83	.075

$^{*}p < .05$, $^{***}p < .001$.

or Math 1050.

Students with a Growth mindset appeared statistically significantly different from students with a Fixed mindset on Exam 2 in Math 1010 and Math 1050. When looking at math mindset, differences between students with a Growth math mindset and a Fixed math mindset were statistically significant only in Math 1010. However, differences appeared to be statistically significant in Math 1050 according to the likelihood ratio test, which seemed to indicate a difference existed between students with a Neutral math mindset and students with a Growth math mindset, although this was not explicitly tested. Details are shown in Table 5.

Students in Math 1010 and Math 1050 did not have a fourth exam before their final exam. Students in Math 1050 did not have a third exam before their final exam.

As noted before with Exam 1, differences in grades based on mindset for Exam 3 were apparent only in Math 1010. As Table 6 shows, the regression analysis predicted as much as a 10.32% points difference between students with a Growth mindset and students with a Fixed mindset. Students with a Neutral

Table 5

Predicting Exam 2 with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	73.01***	−2.25	2.48	.193
	1010	71.79***	1.43	7.67***	< .001
	1050	83.95***	3.78	3.31*	.108
Math	990	73.07***	2.89	1.91	.633
	1010	73.38***	−.21	6.10***	< .001
	1050	85.15***	−4.28	2.54	.001

*$p < .05$, ***$p < .001$.

Table 6

Predicting Exam 3 with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	63.59***	−4.36	2.20	.160
	1010	63.08***	6.08*	10.32***	$< .001$
Math	990	62.67***	3.00	2.70	.576
	1010	66.29***	−.12	7.30***	$< .001$

There was no third exam for Math 1050.
*$p < .05$, ***$p < .001$.

mindset were also seen to be statistically significantly different from students with a Fixed mindset with an expected grade difference of 6.08% points for the exam.

Differences were also apparent for math mindset in Math 1010 but were smaller at 7.30% points difference comparing Growth math mindset to Fixed math mindset. No other differences were statistically significant for math mindset.

As seen in Table 7, only students in Math 990 had a fourth exam before their final exam. Overall differences between the mindsets did not appear statistically significant according to likelihood ratio tests for mindset or math mindset. However, comparing students with a Growth mindset to students with a

Table 7

Predicting Exam 4 with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	67.32***	1.43	6.25*	.085
Math	990	69.38***	7.02	3.11	.320

There was no fourth exam for Math 1010 or Math 1050.
*$p < .05$, ***$p < .001$.

Fixed mindset indicated a statistically significant difference between them with a grade difference as large as 6.25% of points.

The regression analyses for final exam scores are shown in Table 8. Differences in mindset appeared statistically significant in Math 1010 and Math 1050. Comparing students with a Growth mindset to students with a Fixed mindset in Math 990 revealed a statistically significant difference as well. The predicted grade difference between students with a Growth mindset and those with a Fixed mindset ranged between 6.69% and 7.86% of points.

Differences in math mindset were apparent in Math 1010 and Math 1050 as well. In both of these courses, students with a Growth math mindset were predicted to score between 4.76% and 5.64% points higher than those with a Fixed math mindset. In Math 1050, students with a Neutral math mindset were expected to score 5.48% points less than those with a Fixed mindset. This difference was not statistically significant, but there was likely a statistically significant difference comparing students with a Neutral math mindset to those with a Growth math mindset, though this test was not explicitly made.

Table 8

Predicting Final Exam with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	55.17***	3.26	6.92*	.055
	1010	64.70***	6.34*	7.86***	$< .001$
	1050	70.26***	4.57	6.39***	.004
Math	990	57.02***	5.42	4.45	.252
	1010	67.36***	−1.51	5.64**	$< .001$
	1050	72.29***	−5.48	4.76*	$< .001$

*$p < .05$, **$p < .01$, ***$p < .001$.

Comparing Table 4 through Table 8, mindset predicted a statistically significant difference for students with a Growth mindset compared to students with a Fixed mindset for each exam in Math 1010. The level of significance for each coefficient in the regression models also remain at the same level, with the exception of Neutral mindset in Math 1010 on Exam 2.

Dweck (2008) also reported that differences between those with Growth mindsets and Fixed mindsets tend to appear after students have encountered difficulty or setbacks. The intercept in each predicted model represented the expected average of students with a Fixed mindset. By looking at the intercepts for the various exams, we can get an idea of where or when students with a Fixed mindset may have encountered difficulty in the course.

For example, in Math 990, students with a Fixed mindset were expected to score an average of 79% for the first exam, 73% for the second exam, and then 64% for the third exam. For the first through the third exam, predicted differences Growth and Fixed mindset were no larger than 2.5% and the Growth coefficients were non-significant. Differences in grades comparing a Fixed mindset to a Growth mindset were statistically significant on the fourth exam where the expected grade difference was 6.25% of points. This statistically significant difference continued in the final exam with an expected difference of 6.92% of points.

Dweck (2008) observed that differences between students with a Growth mindset and those with a Fixed mindset would begin to appear after students encountered a setback. Because the expected score for a student with a Fixed mindset was 64%, this indicated their average score was close to 64%, a failing grade. The differences which appeared in Exam 4 and on the final exam are consistent with Dweck's findings.

In Math 1050, the differences between students with a Growth mindset and students with a Fixed mindset begin to be statistically significant on Exam 2. The predicted grade for a student with a Fixed mindset was 79% for Exam 1, a passing grade, but the appearance of differences in Exam 2 may suggest that students encountered difficulty in Math 1050 between Exam 1 and Exam 2 according to Dweck's hypothesis. The largest differences appeared on the final exam where students with a Growth mindset were predicted to score 6.39% points more than students with a Fixed mindset.

Successful Completion of Courses

Each model presented in Table 9 was calculated using logistic regression with "Pass" as the dependent variable. All models predict the probability that a student passes the course they are enrolled in.

As noted in Table 9, mindset did not appear to have a statistically significant effect on pass rates in Math 990, though students with a Growth

Table 9

Predicting Pass Rates with Mindset

Mindset	Course	Intercept	Neutral	Growth	Likelihood ratio test
Dweck	990	.29	−.11	.45	.139
	1010	−.33	.99**	1.10***	< .001
	1050	1.96***	−.41	.11	.495
	1050A	.96***	.32	.69*	.070
Math	990	.20	.66	.50	.158
	1010	.10	−.07	.71***	< .001
	1050	1.56***	−.61	.69	.002
	1050A	.83***	−.40	.99***	< .001

1050A represented the adjusted scores for students in Math 1050.
*$p < .05$, ***$p < .001$.

mindset had the highest pass rate as shown by the Growth coefficient being positive and higher than the Neutral coefficient. When using math mindset, no statistically significant differences were apparent.

Mindset appeared to have a statistically significant effect on students' pass rate in Math 1010 for both Dweck's mindset and math mindset. The log-odds ratio, which is the coefficient of the logistic regression model, comparing students with a Growth mindset to students with a Fixed mindset was 1.10. This means the odds of passing for a student with a Growth mindset were 3.00 times the odds for a student with a Fixed mindset. A positive effect was also noticed for a Growth math mindset. Because the intercept in the mindset model was negative (though not statistically significant) it indicated that a student with a Fixed mindset was more likely to fail than to pass in Math 1010.

In Math 1050, mindset did not appear to affect pass rates significantly. Students with a Fixed mindset were predicted to pass the course more often than they failed according to the intercept of the model. When looking at the adjusted math course, differences in pass rates appeared for both mindset and math mindset. After adjusting grades, students with a Growth math mindset were more likely to pass than students with a Neutral math mindset. Approximately 90.47% of students with a Growth math mindset were predicted to pass Math 1050 after adjusting grades, but only 69.64% with a Fixed math mindset and 60.59% with a Neutral math mindset.

Relationship between Outcomes and Other Factors

The coefficients for each predictor variable (each reported from a separate statistical analysis–except categorical variables with more than two categories) are summarized in Appendix C.

Outcomes and Gender

Table 10 shows predicted grades for students by gender, with the baseline group being male students. In Math 990 and Math 1010, women were expected to perform better than men by 3.79 and 2.31, respectively, in percent of points earned ($p < 0.10$ for both). In Math 1050, women performed on average equal to men, with only an observed difference of 0.6% points less for women than men (not statistically significant).

Women were more likely to pass Math 990 than men. The odds of a woman passing were 1.67 times the odds of a man passing in Math 990. This effect diminishes in Math 1010, and reverses in Math 1050, though the effects for these two courses were not statistically significant.

Outcomes and Math Preparation

This section includes effects from students' multiplication skills, effects from prior math courses, including whether they passed their prior math course, and effects from time since prior math class.

Multiplication Skills. The one-minute timed multiplication facts assessment

Table 10

Predicting Outcomes with Gender

Outcome	Course	Intercept	Female
Grades	990	68.59***	3.79
	1010	71.66***	2.31
	1050	82.77***	−.62
Pass	990	.30	.51*
	1010	.55***	.12
	1050	2.09***	−.20

*$p < .05$, ***$p < .001$.

was used to assess the relationship between students' math skills with regard to fluency with basic multiplication facts and achievement in the course. The number of items skipped was recorded for each student and included as a predictor variable, but was not statistically significant for any course. Effects are summarized in Table 11.

In Math 990, where students may not use a calculator during the exams and are discouraged from depending on a calculator for their homework, the number of items students answered incorrectly had a statistically significant effect ($p < .05$). Each item incorrect decreased a students' predicted grade by 1.47 percent of points. Since all students scored between 0 and 8 incorrect, the grades were expected to differ by at most 11.76% when comparing the highest to the lowest number incorrect.

Students in Math 990 showed a decrease in pass rates as their errors on the one-minute timed multiplication facts assessment increased. The logistic coefficient was $-.14$ ($p < .05$). This means a student who missed 8 questions would have .33 times the odds of passing as a student who missed 0 questions.

Table 11

Predicting Outcomes with Multiplication Facts

		Correct		Incorrect	
Outcome	Course	Intercept	Per item	Intercept	Per item
Grades	990	68.00***	.10	72.88***	−1.47*
	1010	69.27***	.13*	73.10***	−.10
	1050	76.65***	.09*	83.20***	−.58
Pass	990	.30	.01	.81***	−.14*
	1010	.31	.01	.60***	.01
	1050	1.50***	.02	2.10***	−.08

$^{*}p < .05$, $^{***}p < .001$.

In Math 1010, the number correct had a positive effect and was statistically significant ($p < .05$). The effect for Math 1010 was .13% points increase per correct answer. When comparing a student who answered 20 items correctly to a student who answered 60 items correctly, the expected grade difference was 5.20% in Math 1010. The number of items correct was not statistically significant in predicting students' probability of passing in Math 1010.

In Math 1050, the number correct had a positive effect and was statistically significant ($p < .05$). The effect was only .09% points increase per correct answer. When comparing a student who answered 20 items correctly to a student who answered 60 items correctly, the expected grade difference was 3.60% points. The number of items correct was not statistically significant in predicting students' probability of passing. However, the intercept was statistically significant and positive, and indicated that a student who answered no questions correctly on the one-minute timed multiplication facts assessment was predicted to pass 82.76% of the time in Math 1050.

Years Since Prior Math Course. Data for the effects predicted from years since prior math course is summarized in Table 12. Students in Math 990 did not have statistically significant effects on grades or pass rates predicted by years since prior math course.

Students in Math 1010 showed a statistically significant increase of 1.07 to their percent of points earned per year since their prior math course. A statistically significant effect was also found on the pass rates. A student who has not taken a math course for 5 years was predicted to have 2.34 times the odds of passing as a student who had taken a math course within the last year.

In Math 1050, students' percent of points earned was predicted to increase per year since their prior math course and the effect was statistically significant,

Table 12

Predicting Outcomes with Years Since Prior Math Course

Outcome	Course	Intercept	Per year
Grades	990	69.79***	.37
	1010	70.09***	1.07***
	1050	81.60***	.57*
Pass	990	.69***	−.02
	1010	.21	.17***
	1050	1.85***	.11

*$p < .05$, ***$p < .001$.

though the effect was smaller at .57 percent points per year since their prior math course. No statistically significant effect was found on pass rates, though the logistic regression model intercept predicts a student who enrolls in Math 1050 within a year of their prior math course has an 86.41% chance of passing Math 1050.

Passing Prior Math Course. For students in Math 990, passing their prior math course predicted a percent of points earned increase of 4.34, as noted in Table 13. However, this effect was not statistically significant. Despite the effect on grades not being statistically significant, passing their prior math course predicted a statistically significant increase in students' odds of passing. A student who passed their prior math course was predicted to have 1.95 times the odds of passing as a student who did not pass their prior math course.

In Math 1010, students who passed their prior math course were predicted to score 3.71 percentage points higher than their peers who did not. The effect was statistically significant and a similar effect was noticed for pass rates. Students who passed their prior math course were predicted to have 1.68 times the odds of

Table 13

Predicting Outcomes with Passing Prior Math Course

Outcome	Course	Intercept	Passed
Grades	990	67.21***	4.34
	1010	69.81***	3.71*
	1050	80.07***	2.89
Pass	990	.04	.67*
	1010	.19	.52**
	1050	1.76***	.29

*$p < .05$, **$p < .01$, ***$p < .001$.

passing as students who did not.

No statistically significant effects were predicted for Math 1050. However, the intercept on the logistic regression was positive and statistically significant, which indicated that a student who did not pass their prior math course had an 85.32% chance of passing.

Prior Math Course. Student's prior math course was coded into 5 levels which were considered to be ordinal. The baseline group (level 0) represents pre-algebra and beginning algebra courses (Math 990 equivalent or prerequisite). Level 1 represented courses similar to Math 1010, level 2 represented courses similar to an introductory statistics course (1000 level stats course), level 3 represented courses similar to Math 1050 or Math 1060 (Trigonometry), and level 4 represented courses in calculus or more advanced mathematical topics. Details on which courses were grouped into which levels can be viewed in Table 25 in Appendix B.

Table 14 details the effects of each course level for prior math course using a common baseline group (level 0) while using the levels as a categorical variable.

Table 14

Predicting Outcomes with Prior Math Course (Categorical)

Outcome	Course	Intercept	Level 1	Level 2	Level 3	Level 4	Likelihood ratio test
Grades	990	66.50***	4.90*	8.61	8.90**	5.78	.039
	1010	65.55***	4.10*	13.66***	12.57***	14.79***	$<.001$
	1050	84.96***	−4.93	.10	−1.93	5.17	$<.001$
Pass	990	.27	.46	.34	.63	.13	.308
	1010	−.20	.55**	1.15***	1.60***	1.85***	$<.001$
	1050	1.61	.14	.82	.53	1.47	.095

*$p < .05$, **$p < .01$, ***$p < .001$.

In Math 990, student achievement seemed dependent on which course they most recently took regardless of whether they passed. Higher level courses generally resulted in higher expected percentage of points earned than lower level courses. The only break in the pattern was for those who had previously taken calculus level courses, which accounts for only a small number of students. Students who had last taken Math 990 or equivalent were predicted to have a course grade of 66.50%. In other words, the model predicted that students who have taken Math 990 or equivalent before enrolling in Math 990 in Fall 2014 (this may represent a student who was retaking the course) would have a failing course grade.

Despite prior math course predicting some differences in percent of points earned, no statistically significant differences in pass rates were observed in Math 990 based on prior math course.

In Math 1010, higher level courses generally resulted in higher expected percents of points earned than lower level courses with the exception of Level 2. All course groups in the model were statistically significantly different from the baseline group with an observed difference of 14.79 percentage points between students who had previously taken calculus and students who had previously taken Math 990 or equivalent.

Pass rates in Math 1010 also appeared approximately linear in log-odds according to the logistic regression model, where higher level courses predict higher pass rates. The odds of passing for a student who took calculus or equivalent prior to Math 1010 was predicted to be 6.36 times the odds of passing for a student who took Math 990 or equivalent prior to Math 1010.

A likelihood ratio test on prior math course for Math 1050 showed that differences existed among the different classifications of math courses ($p < .001$). Though no classification appeared statistically different from the baseline group, which was students who had most recently taken Math 990 or equivalent, those who had previously taken Math 1010 or equivalent and those who had previously taken Calculus or equivalent had the largest predicted difference between them as seen in Table 14. This difference was most likely statistically significant, though no formal tests were made. The grade difference for these two groups was predicted to be 10.10%. However, a likelihood ratio test for Math 1050 indicated no statistically significant differences in pass rates among students who took different levels of math courses prior to enrollment in Math 1050 ($p = .095$).

Similar patterns of increase were observed when considering prior math course as an ordinal variable, as noted in Table 15. In Math 990 an increase of 2.69% points in grade was predicted for each increase of level for prior math course. Pass rates did not appear to be statistically significantly impacted by prior math course.

Percent of points earned in Math 1010 were predicted to increase by 4.07% points per level of prior math course, which was found to be highly statistically

Table 15

Predicting Outcomes with Prior Math Course (Ordinal)

Outcome	Course	Intercept	Per level
Grades	990	67.78***	2.69**
	1010	65.92***	4.07***
	1050	77.70***	2.35***
Pass	990	.42**	.17
	1010	−.17	.51***
	1050	1.47***	.28*

*$p < .05$, **$p < .01$, ***$p < .001$.

significant. The model predicted a grade difference of 16.28% between students who had previously taken calculus or equivalent to students who had previously taken Math 990 or equivalent.

The effect of prior math course on pass rates was most notable in Math 1010 where the log-odds of a student passing increased by 0.51 per level. This means the odds of a student passing, who had previously taken calculus or equivalent, were 7.69 times the odds of a student passing who had last taken Math 990 or equivalent.

Homework Completion. In Math 990, students were predicted to score .79 percentage points in their final grade for every percent of homework completed. Based on the model in Table 16, a student who completed no homework was predicted to score 6.60% on their final grade, while a student who completed all assignments was expected to score 85.60% on their final grade. Homework accounted for 35% of the final course grade in Math 990.

A correlation of $r = .87$ was observed between percent of points earned and homework completion in Math 990. This implied that homework completion

Table 16

Predicting Outcomes with Homework Completion

Outcome	Course	Intercept	Percent completed	Correlation (r)
Grades	990	6.60***	.79***	.87***
	1010	15.99***	.67***	.73***
Pass	990	-7.61***	.10***	.64***
	1010	-5.85***	.08***	.55***

***$p < .001$.

accounted for 76% of the variability in percent of points earned in Math 990. A correlation of $r = .64$ was observed between students who passed the course and their homework completion. Both correlations were highly statistically significant.

The logistic model predicted large differences in pass rates. In Math 990, students who completed no homework were predicted to have a pass rate of .05% (1 out of every 2000), while students who completed all homework assignments (regardless of scores) had a predicted pass rate of 91.61%.

In Math 1010, students were predicted to score .67 percentage points in their final grade for every percent of homework completed. From the model, a student who completed no homework was predicted to score 15.99% on their final grade, while a student who completed all assignments was expected to score 82.99% on their final grade. Homework accounts for approximately 14% of the final course grade in Math 1010.

A correlation of $r = .73$ was observed between percent of points earned and homework completion in Math 1010. This implies that homework completion accounts for 53% of the variability in percent of points earned in Math 1010. A correlation of $r = .55$ was observed between students who passed the course and their homework completion. Both correlations were highly statistically significant.

Large differences in pass rates were also observed for students in Math 1010. Students who completed no homework assignments had a predicted pass rate of .29% (about 1 in every 348), while students who completed all homework assignments (regardless of scores) had a predicted pass rate of 89.57%.

No homework grades were collected in math 1050, as previously explained.

Outcomes and Experiences Since High School

Table 17 details the effects of the six types of breaks in education that were tested. Four explicit breaks were used and the time for each was recorded from students with a fifth category for all other types of breaks. The sixth variable (Total Time) was calculated as the sum of the time spent in each of the five break categories.

Time spent working was observed to have a statistically significant positive effect on students' grades in Math 990. The predicted grade increase was .84% per year spent working. The range of values for time worked varied from 0 to 20 years. The model predicted that students who worked 10 years between high school and college would score 8.4% points higher than students who spent no time working before attending college.

No other breaks in education appeared to have a statistically significant effect in Math 990. No effects were observed in pass rates from any type of break in education. Although time spent working appeared to statistically significantly increase students' percent of points earned, it appeared to have no effect on students' probability of passing.

In Math 1010, the amount of time students spent in religious service appeared to have a statistically significant positive effect. Students showed an increase by 2.13% points increase per year spent in religious service. Most of the

Table 17

Predicting Outcomes with Experiences Since High School

		Military Time		Stay Home Time		Worked Time	
Outcome	Course	Intercept	Per year	Intercept	Per year	Intercept	Per year
Grades	990	71.01***	.93	71.15***	−.07	70.40***	.84*
	1010	72.88***	.31	72.88***	.13	72.94***	.03
	1050	82.36***	−1.42	82.26***	.17	82.28***	−.04
Pass	990	.61***	.07	.65***	−.09	.60***	.01
	1010	.63***	−.03	.63***	−.04	.63***	−.00
	1050	2.03***	−.01	2.04***	−.08	2.08***	−.09

		Rel. Serv. Time		Other Time		Total Time	
Outcome	Course	Intercept	Per year	Intercept	Per year	Intercept	Per year
Grades	990	71.13***	−.02	71.31***	−5.23	70.31***	.48
	1010	71.92***	2.43**	72.84***	.81	72.63***	.24
	1050	81.85***	1.06	82.30***	−3.69	82.23***	.04
Pass	990	.61***	.05	.64***	−.74	.64***	−.02
	1010	.51***	.30**	.62***	.10	.62***	.01
	1050	1.96***	.24	2.03***	−.41	2.10***	−.05

*$p < .05$, **$p < .01$, ***$p < .001$.

students who reported religious service served for at least one year. Values ranged from 0 to 3 years. For two years of religious service, a student was predicted to have 4.26 percentage of earned points more than a student who did not give any religious service between high school and college. No other breaks in education appeared to have a statistically significant effect on percent of points earned for Math 1010.

Religious service was observed to have a statistically significant positive effect on students' pass rates in Math 1010. A student who spent two years in religious service had 1.82 times the odds of passing as a student who did not. No other breaks in education had statistically significant effects on pass rates in Math 1010.

No breaks appeared statistically significant on percent of points earned or pass rates in Math 1050 at $\alpha = .05$.

Outcomes and Math Anxiety

LMA was found to be more correlated to students' percent of points earned than MEA. By scanning Table 18, the LMA coefficient was larger in magnitude than the MEA coefficient for each regression, and showed stronger correlation as seen in Table 19.

In Math 990, LMA had a statistically significant negative effect on students' grades, decreasing their percent of points earned by 3.10 per level of anxiety. The AMAS score and MEA subscore effects were not statistically significant. Only LMA had a statistically significant correlation with percent of points earned ($r = -.13$, $p < .01$).

Table 18

Predicting Outcomes with Math Anxiety

		Anxiety		LMA		MEA	
Outcome	Course	Intercept	Per level	Intercept	Per level	Intercept	Per level
Grades	990	76.96***	−2.00	78.54***	−3.10*	70.51***	.14
	1010	82.45***	−3.39***	80.70***	−3.51***	79.98***	−1.98**
	1050	92.24***	−3.49***	90.22***	−3.45***	90.29***	−2.22***
Pass	990	1.81***	−.39**	1.67***	−.42**	1.16**	−.15
	1010	1.75***	−.40***	1.46***	−.37***	1.56***	−.26***
	1050	4.26***	−.76***	3.78***	−.73***	3.60***	−.44**

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 19

Correlations between Anxiety Factors and Outcomes

Course	Variable	Anxiety	LMA	MEA
Math 990	Grade	$-.08$	$-.13^{**}$	$.01$
	Pass	$-.14^{***}$	$-.16^{***}$	$-.06$
	Anxiety		$.87^{***}$	$.84^{***}$
	LMA			$.46^{***}$
Math 1010	Grade	$-.14^{***}$	$-.15^{***}$	$-.10^{***}$
	Pass	$-.14^{***}$	$-.14^{***}$	$-.12^{***}$
	Anxiety		$.90^{***}$	$.89^{***}$
	LMA			$.60^{***}$
Math 1050	Grade	$-.24^{***}$	$-.24^{***}$	$-.19^{***}$
	Pass	$-.18^{***}$	$-.20^{***}$	$-.13^{***}$
	Anxiety		$.90^{***}$	$.89^{***}$
	LMA			$.61^{***}$

$^{**}p < .01$, $^{***}p < .001$.

However, pass rates were negatively impacted by the AMAS score. Despite this, the effect of the LMA subscore on pass rates was larger in magnitude. The correlation between pass rates and the AMAS score was $r = -.14$ ($p < .001$), while the correlation between pass rates and the LMA subscore was $r = -.16$ ($p < .001$).

In Math 1010, the effect of anxiety was statistically significant for each of the three anxiety scales. LMA predicted the largest change in percent of points earned at 3.51 decrease per level of increased anxiety. A student with the lowest LMA rating was predicted to score 14.04 percentage points higher than a student with the highest LMA rating. The correlations between percentage of points earned and each of the anxiety scores were $r = -.14$, $r = -.15$, and $r = -.10$ for the AMAS, LMA, and MEA respectively.

Anxiety also had statistically significant negative effects on pass rates in

Math 1010. The largest change in the log-odds for passing per level of anxiety was predicted for the AMAS. Based on this model, a student with the lowest level of anxiety would be predicted to have 4.95 times the odds of passing as a student with the highest level of anxiety. As with grades, the correlation between pass rates and the three anxiety scores were all statistically significant. However, the AMAS scale was approximately the same as LMA scale for students in Math 1010.

In Math 1050, each of the anxiety scores had statistically significant negative effects on percent of points earned ($p < .001$). The AMAS score was largest in magnitude and predicted a student with the lowest anxiety level to score 13.96% points higher than a student with the highest level of anxiety. The correlations between percentage of points earned and each of the anxiety scores were statistically significant and largest for Math 1050 compared with Math 990 and Math 1010. A correlation of $r = -.19$ was observed for MEA and a correlation of $r = -.24$ for both the AMAS and LMA.

Anxiety also had a statistically significant impact on student pass rates in Math 1050. The largest effect size was $-.76$ per level of general math anxiety. Using the model, a student with the lowest level of anxiety had a predicted pass rate of 97.07% compared to 61.30% for a student with the highest level of anxiety. The correlations between the pass indicator and anxiety ranged from $r = -.13$ for MEA and $r = -.20$ for LMA, and all were statistically significant.

Outcomes and Math Attitudes

Table 20 contains the models obtained through analysis with each of the four Dartmouth Attitude factors.

In Math 990, only the Interest factor had a statistically significant effect on students' percent of points earned. The coefficient of 3.29 predicted grade

Table 20

Predicting Outcomes with Dartmouth Attitudes

		Ability		Interest	
Outcome	Course	Intercept	Per level	Intercept	Per level
Grades	990	62.19***	3.05	62.94***	3.29*
	1010	54.58***	5.88***	62.56***	3.92***
	1050	66.28***	5.16***	73.62***	3.15***
Pass	990	−.05	.23	−.47	.46**
	1010	−1.38***	.65***	−.53*	.45***
	1050	−.98	.99***	.71	.48***

		Personal Growth		Utility	
Outcome	Course	Intercept	Per level	Intercept	Per level
Grades	990	69.64***	.51	65.28***	2.07
	1010	65.54***	2.64**	62.99***	3.37***
	1050	78.60***	1.40	76.36***	2.02***
Pass	990	.56	.02	.11	.18
	1010	−.01	.23*	−.48*	.38***
	1050	1.07	.33	1.08*	.31*

*$p < .05$, **$p < .01$, ***$p < .001$.

differences of 13.16% between students with the highest level of Interest and students with the lowest level of Interest. Pass rates were also impacted by students' Interest and predicted that a student with the highest level of Interest would have 6.30 times the odds of passing as a student with the lowest level of Interest. Percent of points earned and Interest has a correlation coefficient of $r = .13$ ($p < .05$).

All Dartmouth attitude factors appeared to have a statistically significant effect on percentage of points earned in Math 1010. The largest observed coefficient among models predicting percent of points earned was 5.88 for Ability, which was students' self-perceived math ability. The model predicted grade differences of 23.52% between students with the highest level of Ability and students with the lowest level of Ability. Pass rates were also impacted by students' Ability rating more than other Dartmouth attitudes. The model predicted that a student with the highest level of Ability would have 13.46 times the odds of passing as a student with the lowest level of Ability. Percent of points earned and Ability had a correlation coefficient of $r = .19$ ($p < .001$).

In Math 1050, only Personal Growth did not appear statistically significant in affecting students' percent of points earned or pass rates. The largest observed coefficient among models predicting percentage of points earned was 5.16 for Ability. The model predicted grade differences of 20.64% between students with the highest level of Ability and students with the lowest level of Ability. The largest effect on pass rates was also students' Ability rating. A student with the highest level of Ability was predicted to have 52.46 times the odds of passing as a student with the lowest level of Ability. The percent of points earned and Ability had a correlation coefficient of $r = .26$ ($p < .001$).

Squared Correlation and Partial Correlation Coefficients

The following tables represent the R^2 values observed by using the single variable indicated in each column row as a single predictor variable for the outcome variable (percent of points earned). The partial R^2 values were calculated by comparing the full model (containing all variables presented in the table) to a reduced model using only the variable indicated in that row. Recall that high total R^2 values are desirable while low partial R^2 values are desirable because the partial R^2 values indicate the proportion of the variability in the response variable that was further explained by including all variables in the full model.

Under ideal circumstances, when there are no missing values for predictor variables of any observation, variables with the highest R^2 value will have the lowest partial R^2 value when we are comparing all reduced models to the same full model. However, because there are missing values for each predictor, and these missing values do not align perfectly among predictor variables, the full model has fewer degrees of freedom than any of the reduced models containing only one predictor. As a result, the order of the partial R^2 values (from lowest to highest) may differ from the order of R^2 values (from highest to lowest). Therefore, both were calculated and presented.

In Table 21, which gives the R^2 values for statistically significant predictor variables in Math 990, student interest as measured by the Dartmouth survey, indicated the strongest prediction of percent of points earned. As much as 1.79% of the variability in the percent of points earned was explained by students' interest in mathematics. However, because of missing values, Interest had a higher

Table 21

Predictability of Variables on Percent of Points Earned for Math 990

Variable	R^2	Variable	Partial R^2
Interest	1.79	Math Facts Incorrect	6.09
Mindset	1.76	Interest	6.33
LMA	1.75	Mindset	6.36
Math Facts Incorrect	1.40	LMA	6.37
Worked Time	1.08	Ability	7.19
Ability	.89	Anxiety	7.46
Anxiety	.59	MEA	8.01
MEA	.00	Worked Time	9.29

Reported as percentages.

partial R^2 than the number of math facts students answered incorrectly.

Students' mindset and LMA also had R^2 values greater than 1.7%. Because the R^2 values for Interest, mindset, and LMA were very similar to each other, we suspected all of them were approximately equal in their predictive ability. They also all had very similar partial R^2 values.

However, in comparing the range of predictable values for these three predictors, Interest had the largest range of predictable values, LMA the next highest, and mindset the smallest. Mindset, a categorical variable with three levels, had two degrees of freedom.

Ability, anxiety, and MEA did not have as large an effect on percent of points earned in Math 990, and each has an R^2 value less than 1%. The partial R^2 values followed a similar order (comparing lowest partial R^2 to highest R^2), except that the number of math facts incorrect has a lower partial R^2 than the other variables tested, and time spent working has a higher partial R^2 than the other variables tested. This seems to indicate that time spent working was not as strong a predictor as student interest, mindset, LMA, or math facts correct, and also that the effect from time spent working was more independent of the other predictor variables (in terms of collinearity).

In Table 22, which gives the R^2 values for statistically significant predictor variables in Math 1010, student mindset explained the most variability in percent of points earned. As much as 3.89% of the variability in the percent of points earned was explained by students' mindset.

Also above 3.7% for R^2 was students' Interest and Ability ratings. The R^2 values for mindset, Interest, and Ability are all very similar and suggested similar prediction capabilities. The next highest value was LMA with $R^2 = 2.33\%$. This suggested that mindset was a stronger predictor of percent of points earned than

Table 22

Predictability of Variables on Percent of Points Earned for Math 1010

Variable	R^2	Variable	Partial R^2
Mindset	3.89	Mindset	5.62
Interest	3.83	Interest	6.97
Ability	3.74	Ability	7.06
LMA	2.33	LMA	7.86
Anxiety	2.09	Anxiety	8.09
Religious Service Time	1.13	MEA	9.02
MEA	1.09	Math Facts Correct	9.32
Math Facts Correct	.67	Religious Service Time	14.03

Reported as percentages.

LMA, even though LMA predicted a larger range of values. Mindset also was a stronger predictor than Ability or Interest, even though Ability had a prediction range twice that of mindset.

The partial R^2 values for these predictors followed the same order as those for R^2 values, with the exception of the last three predictors, religious service time, MEA, and number of math facts correct. Time spent in religious service had the largest R^2 value of these three predictor variables, but also had the largest partial R^2 of all predictor variables. The large partial R^2 value indicated that 14.03% of the variability in percent of points earned which was not predicted by time spent in religious service was explained by the other predictor variables. This indicated that the variability in percent of points earned predicted by time spent in religious service was likely more independent of the other variables (in terms of collinearity).

In Table 23, which gives the R^2 values for statistically significant predictor variables in Math 1050, the Dartmouth Ability and Interest ratings explained the most variability in percent of points earned, followed closely by LMA and overall

Table 23

Predictability of Variables on Percent of Points Earned for Math 1050

Variable	R^2	Variable	Partial R^2
Ability	6.69	Ability	4.59
Interest	6.25	Interest	5.04
LMA	5.95	LMA	5.47
Anxiety	5.82	Anxiety	5.60
MEA	3.56	MEA	7.82
Math Facts Correct	1.12	Math Facts Correct	9.92
Mindset	1.03	Mindset	10.16

Reported as percentages.

math anxiety. Students' mindset explained the least variability in the percent of points earned, with only 1.03%.

Of the three math anxiety factors, LMA had the largest prediction accuracy and explained 5.95% of the variability in percent of points earned. MEA only explained 3.56% of the variability in percent of points earned, which further indicated that LMA was a better predictor of student achievement than MEA. It is again good to note that for approximately 90% of all students in Math 1050 during this semester, the variability in percent of points earned came from exams only; yet, MEA did not explain much of this variability.

Mindset had the lowest R^2 value and the highest partial R^2 value. This indicated that mindset was not a strong predictor in Math 1050, compared to the other variables tested, in explaining the variability in the percent of points earned. Mindset did not have a statistically significant effect when predicting percent of points earned for students in Math 1050, while other variables in Table 23 had a statistically significant effect.

Discussion and Conclusions

A summary of major factors is summarized in Table 26 in Appendix C for easy comparison. Each entry represents the effect due to the given variable as reported in the corresponding linear or logistic regression with only the indicated factor entered in the model (with the exception of the categorical variable mindset).

Table 27 in Appendix C compares the effects from time spent in breaks in education with each entry being the effect reported in the linear or logistic regression model as appropriate. Each entry used only the indicated variable in each column in the predictive model and the effect was recorded.

Relationship between Mindset and Outcomes

We compared two mindset constructs with outcomes: Dweck's general mindset and math mindset, in which the mindset items specifically included reference to math. Both constructs resulted in students being classified with Fixed, Neutral, or Growth mindsets.

Dweck's mindset predicted differences among students on the percentage of points earned for each course, although the analysis was not statistically significant at $\alpha = .05$ for Math 1050. In Math 1010, a large difference of 11.59 in the percentage of points earned was observed for students with a Growth mindset compared to students with a Fixed mindset. The predicted effects for students with a Neutral mindset were also positive, but only statistically significantly different than students with a Fixed mindset in Math 1010. Mindset explained the most variability in the percent of points earned for students in Math 1010, and more variability than any of the three anxiety factors in Math 990.

Students with a Fixed mindset were less likely to pass Math 1010 than students with either a Neutral or Growth mindset. However, no effects of mindset on passing were observed to be statistically significant in Math 990 or Math 1050, despite the differences predicted from Dweck's mindset for the percentage of points earned.

Dweck's mindset appeared to be a good predictor of student achievement on examinations. Dweck's mindset predicted statistically significant differences on all exams in Math 1010 as well as some exams in Math 990 and Math 1050. Furthermore, Dweck claimed that student mindsets could predict performance on one exam based on performance from a previous exam. To explain, Dweck claimed that mindset could predict differences on successive exams among students of different mindsets when students encountered difficulty or setbacks. In other words, if students performed poorly on an exam, then the performance of students with a Fixed mindset would be lower than students with a Growth mindset on the next exam. The results from the analyses of Math 990 exams supported this claim.

Our findings supported Dweck's claim that mindset is a good predictor of student achievement. Dweck also stated that students with a Neutral mindset would perform at a level between students with a Fixed mindset and students with a Growth mindset. Our data supported Dweck's statement.

The concept of math mindset was also investigated, where mindset items included references to math, in particular. Growth math mindset was statistically significant in predicting percent of points earned, but the result was not as large in magnitude as Dweck's mindset for Math 990 and Math 1010. In Math 990, students with a Neutral math mindset were predicted to perform better than students with a Growth math mindset in all analyses of both outcomes. In Math 1010 and Math 1050, students with a Neutral mindset were predicted to perform worse than students with a Fixed math mindset in all analyses for both outcomes.

The overall results of math mindset as constructed herein varied from the general pattern that Dweck reported for mindset, where students with a Growth mindset had higher performance than students with a Neutral mindset, and students with a Neutral mindset had higher performance than students with a Fixed mindset. Because the construct of math mindset only involved four domain-specific question instead of a larger value of eight that was used for Dweck's mindset, this may have resulted in unusual consequences. None of the analyses with math mindset resulted in the general mindset pattern that Dweck observed. However, as noted before, a very consistent pattern appeared in each course, on every analysis performed on outcome variables. This suggested that the construct of math mindset, as coded in the study, was detecting real differences between courses, though it did not fit the expected patterns.

However, when the four math mindset items were used in combination with four non domain-specific items, Dweck's observed pattern did emerge throughout the analyses except when predictions were made for exams 2 and 3 in Math 990, and also in Math 1050 and Math 990 when predictions of pass rates were made.

Relationship between Outcomes and Other Factors

We also investigated the relationship between course outcomes and other factors including gender, gaps in school enrollment, preparation for math, homework submission, math attitudes, and math anxiety.

Anxiety was found to have the strongest effect on student achievement based on the Abbreviated Math Anxiety Scale (AMAS). Our findings suggested that the AMAS factor, Learning Math Anxiety (LMA), may have a stronger effect on student achievement in mathematics than the factor Math Evaluation Anxiety (MEA). Both AMAS and LMA score effects were larger in magnitude than MEA in all courses. The regression models predicted differences in percent of points earned to be between 12.40 and 13.80 percentage points when comparing students with the highest level of LMA to the lowest level of LMA. By comparing the AMAS score to the LMA and MEA subscores, it was found that MEA did not predict statistically significant differences in students' percentage of points earned or pass rates in Math 990. However, MEA did predict differences in percentage of points earned and pass rates of smaller magnitude than LMA and AMAS scores in Math 1010 and Math 1050.

Homework completion was highly statistically significant in predicting both the percentage of points earned in courses and pass rates. Because percent of total points earned was dependent on homework completion for both Math 990 and 1010, the percentage of points earned and percentage of homework submitted were highly correlated. As previously noted, submitting all homework assignments in Math 990 predicted that students would earn 79% of the course points (without considering the score on those assignments) though homework scores accounted for only 35% of students' total points earned. In Math 1010, where homework assignments comprised approximately 14% of students' grades, students were predicted to score 67% of the course's point total just by submitting all assignments.

Large differences in pass rates were observed for Math 990 and Math 1010 for homework completion. In Math 990, students who completed no homework had a predicted pass rate of .05%, while students who completed all homework assignments had a predicted pass rate of 91.61%. Similarly, in Math 1010, students who completed no homework had a predicted pass rate of .29%, while students who completed all homework had a predicted pass rate of 89.57%. All analyses for homework completion provided very strong support for the claim that homework completion aided student achievement.

Students' abilities on a one-minute timed assessment of single digit multiplication facts identified statistically significant differences in the percentage of course points earned. In Math 990, the number of multiplication facts with *incorrect* answers predicted point differences of 1.47% for each item missed. In other words, a student with 10 errors compared to a student with no errors would earn 14.7 percentage points less. In Math 1010 and Math 1050, the number of correct multiplication facts predicted differences in course outcomes. The difference between 20 and 60 multiplication facts answered correctly predicted increases in student success of 5.20 and 3.60 percentage points, respectively. These observations supported Callow-Heusser's (2014) claim that students may be harmed if they enter math courses with low multiplication skills, particularly in Math 990.

Students' prior math courses appeared to have a statistically significant effect on student achievement, particularly in Math 990 and 1010. Grade differences were largest in magnitude in Math 1010 where percentage differences were predicted to be 14.79 out of 100 when comparing students who had previously taken calculus or equivalent to students who had previously taken Math 990 or equivalent. A similar statistically significant effect was observed in pass rates for students in Math 1010. When prior math course was considered as ordinal, the effects on percent of points earned were statistically significant in all three courses and predicted grade differences of one letter grade (10% of total points) or more depending on the course. Pass rates in Math 1010, but not Math 990 or 1050, were also statistically significantly affected by students' prior math course when considered as ordinal. Statistically significant differences were observed for Math 1010 in expected percent of points earned as predicted by students passing their prior math course. Also, passing the prior math course predicted increased pass rates for Math 990 and Math 1010. Hence, adequate preparation in prerequisite courses does appear to have a statistically significant effect on students' success in future math courses.

Four types of gaps in school enrollment were analyzed, including a fifth "other" category, as well as total time spent out of school in other endeavors. Time spent working was found to be statistically significant in improving percentage of points earned in Math 990, though little to no effect was observed for pass rates in the same course. Religious service was observed to have a positive statistically significant effect in Math 1010 on both pass rates and percentage of points earned. The effect on percentage of points earned was 4.86 point for two years of religious service. Jeynes (1999) reported that religious involvement increased minority students' performance in math, and our findings support Jeynes' research by providing evidence of a positive relationship between religious service and math success. Military service and staying home to raise a family did not predict statistically significant effects and were small in magnitude for both course percentage of points earned and pass rates. Time spent in "other" activities was not found to have statistically significant effects on percent of points earned or pass rates but did predict the largest negative effects per year in Math 990 and Math 1050.

The time spent since students' prior math course appeared to have a statistically significant positive effect on percentage of points earned in Math 1010, but these may be the result of influential points (e.g. students who had taken unusually large breaks in math education and had a very high percentage of points earned) or correlated to other factors that were also statistically significant, such as time spent in religious service.

The Dartmouth math attitudes survey resulted in four scales: Ability, Interest, Utility, and Personal Growth. Students' self rating of ability in mathematics had a statistically significant effect on both percentage of points earned and pass rates in Math 1010 and Math 1050. The predicted differences comparing a student of the highest level of Dartmouth's Ability factor to a student of the lowest level were 23.52 and 20.64 percentage points, respectively. Hattie (2009) showed that students' self-perceived ability was a strong indicator of students' future achievement ($d = 1.44$), and our data provided evidence to support findings reported by Hattie and researchers using the Dartmouth survey (Korey, 2000).

Student interest in mathematics as measured by the Dartmouth attitudes survey also had a statistically significant effect on percentage of points earned and pass rates in each course. In fact, effect sizes indicated that student interest predicted more than a letter grade difference between students with the highest rating and students with the lowest rating in all three courses, again providing evidence to support Hattie's (2009) reported effect size of $d = 0.36$. The correlation between percentage of course points and Dartmouth's Interest rating ranged from $r = .13$ ($p < .05$) in Math 990 to $r = .25$ ($p < .001$) in Math 1050. Some of these effect sizes appeared larger than the average $r = .12$ reported by Kishor and Ma (1997).

While students' perception of the utility of math had a statistically significant relationship with the percentage of points earned and pass rates in Math 1010 and Math 1050, the effect sizes were smaller than those observed for the Dartmouth research on math attitudes for the factors of Interest and Ability.

Finally, female students had a statistically significantly higher pass rate in Math 990. Differences by gender did not appear to be statistically significant in other courses. Differences by gender in the percent of points earned were not statistically significant for any course.

Summary of Analaysis and Answers to Research Questions

In response to the question, "Is mindset a good predictor of student outcomes in developmental math courses as measured by overall course grades, scores on exams and/or successful completion of courses?," mindset was found to be a good predictor of student outcomes in developmental math courses, especially in Math 1010 where students with a Growth mindset performed much higher than students with a Fixed mindset. This was confirmed in overall percentage of points earned as well as scores on exams and pass rates in Math 1010 and 990. However, mindset did not generally predict statistically significant differences in percent of points earned or pass rates in Math 1050. Additionally, Dweck's mindset was a stronger predictor of course outcomes than math mindset, in which items included specific references to math.

The second research question investigated the effects of gender, prior math preparation, course study habits, experiences since high school, math-related anxiety, and attitudes towards mathematics and the relation to students' grades as measured by percent of points earned for the course and pass rates. Of these factors, math-related anxiety had one of the largest and most statistically significant effects on students' percent of points earned and pass rates. In particular, the analysis showed that Learning Math Anxiety had a higher predicted effect upon student success than Math Evaluation Anxiety.

Statistically significant differences in points earned were predicted by students' multiplication skills, depending on the course. Years since prior math course appeared to have a statistically significant positive effect for students in

Math 1010, though minimal to no effect in other courses. Students' last math course predicted statistically significant differences in student success, particularly in Math 1010. Gender was found to have little to no effect for Math 1010 and Math 1050, though female students were predicted to have a higher pass rate in Math 990 than male students.

Homework completion was found to have a statistically significant relationship to student success as measured by percentage of points earned, but was also highly correlated to pass rates. If students continue the same habits for homework completion in future math courses, we might predict similar results in their achievement for future courses.

Among experiences students might have had since high school, time spent working had a statistically significant positive effect on percent of points earned for students in Math 990. Time spent in religious service was statistically significant for Math 1010 percentage of points earned and pass rates. Other breaks in education did not have statistically significant effects on student success.

While students' ability in mathematics, as measured by the Dartmouth attitudes survey, predicted the largest differences in percentage of points for students, particularly in Math 1010 and Math 1050, causal relationship was uncertain. Finally, students' interest in mathematics was also found to have a statistically significant effect on percent of points earned and pass rates in all courses, predicting at least a one-letter grade increase in course grades from lowest level of interest to highest level of interest. However, it is likely that students' ability and interest were related.

Limitations

Because this study was an observational study rather than a controlled experiment with random assignment to groups, the results indicated possible relationships among outcomes and various factors, but not causal relationships. As such, results should not be implied to indicate a change that will result with an intervention. Other research that has examined causal relationships should be consulted to identify which interventions may best impact student achievement.

This study was conducted only with those students who volunteered to participate and who were in attendance on the day the surveys were administered to their section. The results were not comprehensive of all students enrolled in these courses.

During the Fall 2014 semester, challenges resulted from a transition from a previous version of WileyPlus online homework system to the new version. As a result, all students in Math 1050 large lecture courses (approximately 90% of all students enrolled in Math 1050) were given 15% of their total points without earning them. It was impossible to know what would have occurred if events happened as intended. In the past, a large percentage of students did little, if any, of the online homework, and would have received a large deduction in points. Some students may have achieved better grades overall through completion of the homework assignments, which may have also increased achievement on exams. Other students may have tried harder in a class based on homework grades. Hence, one cannot predict the changes in outcomes that might have occurred from graded homework.

In an effort to gain a better picture of what impact our predictors may have had on students' actual achievement, an adjusted Math 1050 grade score was created for students in the large lecture sections. This adjustment removed the 15% that large lecture students automatically received for homework and scaled the remaining points to 100%. The adjustment assumed that students would have earned as many points from homework as they earned from exams and quizzes (being weighted by their relative value). While this assumption was oversimplified, it was probably the best indication of what may have happened had everything gone as planned. After adjusting final grade scores accordingly, pass rates were calculated again using the adjusted final grade scores. These adjustments are noted on the tables that involved final grades and pass rates.

Pass rates were obtained for the previous nine Fall semesters for Math 1050, and the average pass rate was 81.75% per semester with a standard deviation of 2.22. If we consider each Fall semester as a random normally distributed variable with common mean and variance, then the Fall 2014 semester upon which this study was based was 2.74 standard deviations above the expected value using the sample mean and standard deviation as estimates for the population mean and standard deviation. From this, we suspect that the Fall 2014 semester may have been substantively different from previous semesters.

We expect the results of this study may be generalized to other semesters at Utah State University, except for the noted changes in ages of leaving for religious service, which may not impact demographics for all future semesters as much as they did in the Fall 2014 semester. However, USU was expecting more students who will have served LDS missions to return in the Fall 2015 semester than were observed for Fall 2014.

These results might be generalizable to other universities with similar demographics of students or for math courses that are similar to those studied. However, because of the difficulty in Math 1050 with homework grading during the Fall 2014 semester, the results for Math 1050 might not be generalizable to future semesters at Utah State University or similar courses anywhere.

Suggestions for Future Research

Mindset appeared to have an approximately linear effect on each outcome variable that was tested. Given the consistent linear pattern, analyses with mindset may be improved if an ordinal scale were used instead of categorical.

Multiplication fact fluency may be an important skill for success in math, as suggested by our findings. It may be worthwhile to improve students' math facts skills during these algebra courses to determine the improvement's effect on math grades.

Religious service was also seen to improve pass rates and course grades in Math 1010. There were also other factors that were strongly correlated with religious service, such as mindset, which may explain the relationship between time spent in religious service and course grades and pass rates. More research could be conducted to identify effects of religious service on student success from a variety of denominations rather than a population which was mostly LDS.

More investigation should be made into comparing the effects of Learning Math Anxiety with Math Evaluation Anxiety. As this evidence suggests, greater efforts should be made to reduce anxiety caused by learning math. Also, the evidence from other researchers (Hattie, 2009; Maloney & Beilock, 2012) and this study suggest that interventions to reduce math anxiety may significantly improve students' course grades and pass rates.

Mindset and math anxiety may be related. Research on interventions to change mindset should assess whether there are commensurate changes in math anxiety.

Conclusions

Of the factors for which an intervention could be provided that were related to student outcomes in math, students' math-related anxiety was found to have the largest statistically significant effect on student achievement, matching the meta-analysis of Hattie, and supporting evidence from Maloney on the effects of anxiety on students' ability to reason. Learning Math Anxiety was a better predictor than Math Evaluation Anxiety in effecting student achievement. Mindset also appeared to be a good predictor of student success in developmental math courses as measured by percentage of points earned and pass rates, supporting Dweck's findings. Students' prior math ability appeared to play a role in student achievement as measured by multiplication skills and the highest level of math previously completed. To help improve students' success in developmental math, interventions to decrease anxiety, change Fixed or Neutral mindsets to Growth mindsets, and increase basic math skills such as multiplication facts fluency seem worthwhile given research evidence. Also, evidence suggested that being appropriately placed into a course for which students are best prepared will increase success.

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APPENDICES

Appendix A. Research Study Forms

Informed Consent Form

Utah State University
Department of Mathematics
3900 Old Main Hill
Logan UT 84322-3900
Telephone: (435) 797-2036

Page 1 of 2
USU IRB Approval: Aug. 27, 2014
Approval Terminates: 08/26/2017
Protocol #6058
IRB Password Protected per IRB Administrator

INFORMED CONSENT

Factors Related to Successful Completion of Developmental Mathematics Courses

Introduction/ Purpose Dr. Catherine Callow-Heusser in the Department of Mathematics and Statistics at Utah State University is conducting a research study to find out more about factors related to successful completion of developmental mathematics courses. You have been asked to take part because you are currently enrolled in a developmental mathematics course. There will be approximately 2200 total participants in this research. Jason Bagley, a Master's student researcher, will assist with the study. This project has no external funding.

Procedures If you agree to be in this research study, you will complete the attached survey now, and again at the end of the semester. You will also complete a 1-minute timed multiplication facts (0-10) assessment. The total time needed to participate in the study is 20 minutes now, and 20 minutes at the end of the semester. Additionally, mathematics course-taking patterns at USU and homework, exam, and final grades in this course will be obtained by the mathematics advisor, Linda Skabelund, and included in the data analysis.

Risks Participation in this research study may involve some added risks or discomforts. These include the potential for a short-duration increase in anxiety during the 1-minute timed multiplication facts assessment. There is a small risk of loss of confidentiality but we will take steps to reduce this risk per research regulations. Because no experimental treatments are involved, we foresee no additional risks.

Benefits The potential benefits to you and others involved in this research, as well as to students who subsequently enroll in developmental math courses, include support services and mathematics advising better targeted to meet students' needs and improve pass rates in developmental mathematics courses.

Explanation & offer to answer questions The project researchers or your instructor has explained this research study to you and answered your questions. If you have other questions or research-related problems, you may reach principle investigator, Dr. Callow-Heusser at (435) 797-2036 or Catherine.Callow-Heusser@usu.edu.

Voluntary nature of participation and right to withdraw without consequence Participation in research is entirely voluntary. You may refuse to participate or withdraw at any time without consequence or loss of benefits. Your course grade will not be affected by participating or refusing to participate. No compensation is provided.

Confidentiality Research records will be kept confidential, consistent with federal and state regulations. Only the investigator and approved student researchers will have access to the data which will be kept in a locked file cabinet or on a password protected computer in a locked room. To protect your privacy, personal, identifiable information will be removed from study documents and replaced with a study identifier. Identifying information will be stored separately from data and will be kept in a password protected file that is destroyed by August 2017.

IRB Approval Statement The Institutional Review Board for the protection of human participants at Utah State University has approved this research study. If you have any questions or concerns about your rights or a research-related injury and would like to contact someone other than the research team,

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Department of Mathematics
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INFORMED CONSENT
Factors Related to Successful Completion of Developmental Mathematics Courses

you may contact the IRB Administrator at (435) 797-0567 or email irb@usu.edu to obtain information or to offer input.

I**nvestigator Statement** "I certify that the research study has been explained to the individual, by me or my research staff, and that the individual understands the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered."

Catherine Callow-Heusser

Catherine Callow-Heusser, Ph.D.	Jason Bagley
Principal Investigator	Student Researcher
Catherine.Callow-Heusser@usu.edu	Jason.Bagley@aggiemail.usu.edu

Signature of Participant:

By signing below, I agree to participate in the study, *Factors Related to Successful Completion of Developmental Math Courses*. I understand the purpose of this research is to investigate ways to improve success rates in developmental math courses such as Math 0990, 1010, and 1050. I give permission for my data and grades to be included in the research study, and understand that my privacy and confidentiality will be maintained per Federal regulations regarding the privacy of research participants. I understand that I can withdraw from the study at any time and that participation in the study or refusal to participate will not affect my grades in the math course.

____________________ ____________________ ________

Printed Name	Signature	Date

Beginning of Semester Data Collection

Procedures for Collecting Data

1. Email the instructor at least one day before to remind them you are coming.
2. Take to class:
   - Copy of the following script
   - One copy of Informed Consent for each student (1 page—green)
   - One copy of Math Survey for each student (2 pages, 1 double sided—white)
   - One copy of Multiplication Math Facts for each student (1 page—white)
3. Pass out Informed Consent (green) and Survey. Read this script to class:

   As you probably know, pass rates in Math 990, 1010, and 1050 are not as high as we'd like--here at USU and nationwide--and too many students drop out or have to retake these courses. We want to learn more about what we can do to change this picture. We are conducting research in the math department to try to improve pass rates in these courses, and collect evidence to know how to better meet students needs. Our goal is to provide supports to help you succeed and enjoy math more--and with less anxiety! We'd like you to help us with that research by completing this math survey and a 1-minute timed multiplication facts assessment. We'll do the same thing at the end of the semester. This will take about 15-20 minutes each time and provide us with valuable information. Your participation is voluntary, and these will not be counted in your grade. You can take the letter on green paper with you to help you understand the study. Any questions? (*pause*)

   The green copy of the Informed Consent is yours to keep. Please sign the Informed Consent statement at top of the Math Survey now if you agree to participate in the research. If you refuse to participate in the research, please sit quietly and work on homework while others complete the survey. (*pause for signatures*)

   Please complete the Math Survey items. Check and make sure you've answered every question. When everyone is done, we'll do the timed multiplication facts.
4. Collect the Math Survey.
5. Pass out Multiplication Facts assessment with these instructions:

   Leave this paper FACE DOWN on your desk. Write your name and A-number on the back. Again, please leave it FACE DOWN and write your name and A-number on the back. You'll turn it over when I say ready. (*give time to write name and A-number, with additional reminders to leave face down, if needed*)

   I'm going to time you for one minute. Please try every problem and DO NOT skip around. In other words, go across each row or down each column and try every problem. If you don't know the answer, skip the problem, but keep going in order. Ready, turn your paper over and begin. (*time for 1 minute*)

   Please turn your papers face down and hand them to the side (or middle, etc.).

   Thank you for participating in the research. If you have questions, our contact information is on the green paper. We'll see you again at the end of the semester.
6. Make sure the course and section number are written on the folders.
7. Place the math survey and the multiplication test in the folders.
8. Return the folders to Cathy so the data can be stored in a locked file cabinet.

Beginning of Semester Survey

UtahState University
Department of Mathematics
3900 Old Main Hill
Logan UT 84322-3900
Telephone: (435) 797-2036

Page 2 of 2
USU IRB Approval: Aug. 27, 2014
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Protocol #6058
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INFORMED CONSENT

Factors Related to Successful Completion of Developmental Mathematics Courses

Signature of Participant:

By signing below, I agree to participate in the study, *Factors Related to Successful Completion of Developmental Math Courses*. I understand the purpose of this research is to investigate ways to improve success rates in developmental math courses such as Math 0990, 1010, and 1050. I give permission for my data and grades to be included in the research study, and understand that my privacy and confidentiality will be maintained per Federal regulations regarding the privacy of research participants. I understand that I can withdraw from the study at any time and that participation in the study or refusal to participate will not affect my grades in the math course.

____ ____________

Printed Name Signature Date

1. In which course are you enrolled now? ❑ Math 0990 ❑ Math 1010 ❑ Math 1050 Section? ______

2. In what year were you born? _______________ 3. What is your gender? ❑ Male ❑ Female

4. What is your first language? ❑ English ❑ Spanish ❑ Other ______________________________

5. How many years of college have you **completed**, recently or in the past? ____________ years

6. At which school did you take your **last** math class? ______________________________________
   a. City? ______________________________________ b. State? ______________________

7. When did you take your **last** math class? ***(Check one)*** ❑ 2014 ❑ 2013 ❑ 2012
   ❑ 2011 ❑ 2010 ❑ 2009 ❑ 2008 ❑ 2007 ❑ 2006 ❑ Other __________

8. Which math class did you take **last** (before this semester)? ❑ Pre-Algebra ❑ Pre-calculus
   ❑ Math 0990 (Beginning Algebra) or equivalent ❑ Algebra I ❑ Calculus I
   ❑ Math 1010 (Intermediate Algebra) or equivalent ❑ Algebra II ❑ Calculus II
   ❑ Math 1050 (College Algebra) or equivalent ❑ Geometry ❑ Math I
   ❑ Math 1210 (Calculus) or equivalent ❑ Trigonometry ❑ Math II
   ❑ Other (describe) ________________________________ ❑ Math III

9. Did you pass your most recent math class? ❑ Yes ❑ No

10. If you had a break in schooling between high school and now, please indicate what you did during that break (or breaks) and for how long. ***(Check all that apply)***
   ❑ Religious service For how long? ____________
   ❑ Military service For how long? ____________
   ❑ Stayed home to raise children For how long? ____________
   ❑ Worked For how long? ____________
   ❑ Other For how long? ____________
   (describe): ____
   ❑ Other For how long? ____________
   (describe): ____

11. What do you plan to major in? ***(Check one)*** ❑ I have no idea ❑ Humanities, Social Sciences
   ❑ Business ❑ Agriculture ❑ Science ❑ Natural Resources
   ❑ Math ❑ Physics ❑ Education ❑ Health, Recreation
   ❑ Computer Science ❑ Engineering ❑ Music, Art ❑ Other (what?) ______________

(Circle one number for each item to indicate your rating from low to high)

On a scale of 1 (Low) to 5 (High), rate the following.	Low				High
12. How much do you enjoy school?	1	2	3	4	5
13. How well do you like math?	1	2	3	4	5
14. How prepared do you feel for this math class?	1	2	3	4	5
15. How prepared do you feel for college?	1	2	3	4	5

Student Number: A______________________ (please write your name if you do not know your A-number)

(Circle one number for each item to indicate your rating from low to high)

Rate your ANXIETY in the following situations.	**Low**				**High**
16. Using a calculator to answer a complex problem.	1	2	3	4	5
17. Thinking about a math test one day before the test.	1	2	3	4	5
18. Watching a teacher work an algebraic equation.	1	2	3	4	5
19. Taking an examination in a math course.	1	2	3	4	5
20. Being given a homework assignment with many difficult problems that is due the next class meeting.	1	2	3	4	5
21. Listening to a lecture in math class.	1	2	3	4	5
22. Listening to another student explain a math formula.	1	2	3	4	5
23. Being given a "pop" quiz in a math class.	1	2	3	4	5
24. Starting a new chapter in a math book.	1	2	3	4	5

Read each statement and rate whether you agree or disagree. *(Check one response for each item to indicate your rating)*	Strongly Disagree	Mostly Disagree	Mostly Agree	Strongly Agree
25. Your **math** intelligence is something very basic about you that you can't change very much.	❑	❑	❑	❑
26. You can learn new things, but you can't really change how intelligent you are in **math**.	❑	❑	❑	❑
27. No matter how much **math** intelligence you have, you can always change it quite a bit.	❑	❑	❑	❑
28. You can always substantially change how intelligent you are in **math**.	❑	❑	❑	❑
29. You are a certain kind of person, and there is not much that can be done to really change that.	❑	❑	❑	❑
30. No matter what kind of person you are, you can always change substantially.	❑	❑	❑	❑
31. You can do things differently, but the important parts of who you are can't really be changed.	❑	❑	❑	❑
32. You can always change basic things about the kind of person you are.	❑	❑	❑	❑

Rate your level of agreement with each statement. *(Check one box for each item to indicate your rating)*	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
33. Overall, I think this course will be very difficult.	❑	❑	❑	❑	❑
34. Even if I try very hard, I do not think I will do as well in math as well as I do in most subjects.	❑	❑	❑	❑	❑
35. The inadequacy of a student's math background can be overcome by good teaching.	❑	❑	❑	❑	❑
36. The low mathematics achievement of some students can generally be blamed on their teachers.	❑	❑	❑	❑	❑
37. I understand mathematics concepts well enough to do well in math.	❑	❑	❑	❑	❑

Rate your level of agreement with each statement. ***(Check one box for each item to indicate your rating)***	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
38. Students' achievement in math is directly related to their teacher's effectiveness in teaching math.	❑	❑	❑	❑	❑
39. I wonder if I have the skills necessary to take this math course.	❑	❑	❑	❑	❑
40. To understand math, I sometimes think about my own experiences.	❑	❑	❑	❑	❑
41. I am good at math.	❑	❑	❑	❑	❑
42. If I work at it, I can do well in math.	❑	❑	❑	❑	❑
43. Most subjects interest me more than math.	❑	❑	❑	❑	❑
44. Math is basically a lot of facts, rules, and formulas to memorize and use.	❑	❑	❑	❑	❑
45. Good math teachers show students the exact way to answer the questions students will be tested on.	❑	❑	❑	❑	❑
46. I enjoy learning new things in math.	❑	❑	❑	❑	❑
47. Math helps me understand the world around me.	❑	❑	❑	❑	❑
48. I have had some math classes that were taught in a very interesting way.	❑	❑	❑	❑	❑
49. Many situations in the world around me can be explained using math.	❑	❑	❑	❑	❑
50. I often feel like I'm missing important skills in math class.	❑	❑	❑	❑	❑
51. I want to study more math.	❑	❑	❑	❑	❑
52. Working in groups helps me learn math.	❑	❑	❑	❑	❑
53. I rarely see situations outside of school that can be explained using math.	❑	❑	❑	❑	❑
54. I try to avoid courses that involve math.	❑	❑	❑	❑	❑
55. When I get stuck on a math problem, I can usually figure it out.	❑	❑	❑	❑	❑
56. Writing about math makes it easier to learn.	❑	❑	❑	❑	❑
57. In math, I can discover things for myself.	❑	❑	❑	❑	❑
58. After I've forgotten all the formulas or rules, I'll still be able to use ideas I've learned in math.	❑	❑	❑	❑	❑
59. I'm never sure my answer is right in math until I'm given the solution.	❑	❑	❑	❑	❑
60. Learning math makes me nervous.	❑	❑	❑	❑	❑
61. Doing math helps me think clearly and logically.	❑	❑	❑	❑	❑
62. I don't really understand math until I work it out for myself.	❑	❑	❑	❑	❑
63. I don't need a good understanding of math to achieve my career goals.	❑	❑	❑	❑	❑
64. Overall, I think this course will be very challenging for me.	❑	❑	❑	❑	❑

End of Semester Survey. Comprising pages 75 to 77.

Student Number: A________________________ (please write your name if you do not know your A-number)

1. In which course are you enrolled? ❑ Math 0990 ❑ Math 1010 ❑ Math 1050 Section? _____

2. Do you feel you are most likely to ❑ Pass this class? ❑ Need to retake this class?

3. Which of the following resources did you use this semester? Indicate your frequency of use by checking the best response.

Resource	Frequency of Use			
a) Student Support Services	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
b) Disability Resource Center	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
c) Private Tutoring	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
d) Drop-in Tutoring Center in the Academic Resource Center	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
e) Instructor-led Study Sessions held outside of regular class time	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
f) Student Athletic Services tutoring/mentoring	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
g) Course instructor's office hours	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
h) Recitation instructor's office hours (if enrolled in Math 1050)	❑ Never ❑ Not Applicable because not enrolled in Math 1050	❑ Once	❑ Occasionally	❑ Frequently
i) Khan Academy	❑ Never	❑ Once	❑ Occasionally	❑ Frequently
j) Other online resources	❑ Never	❑ Once	❑ Occasionally	❑ Frequently

4. If you used online resources other than Khan Academy, what were they?

5. What do you plan to major in? ❑ I have no idea ❑ Humanities, Social Sciences
   ❑ Business ❑ Agriculture ❑ Sciences ❑ Natural Resources
   ❑ Math, Physics ❑ Engineering ❑ Education ❑ Health, Recreation
   ❑ Computer Science ❑ Music, Art ❑ Other (what?) ____________________

(Circle one number for each item to indicate your rating from low to high)

On a scale of 1 (Low) to 5 (High), rate the following.	Low				High
12. How much do you enjoy school?	1	2	3	4	5
13. How well do you like math?	1	2	3	4	5
14. How prepared did you feel for this math class?	1	2	3	4	5
15. How prepared do you feel for college?	1	2	3	4	5

Student Number: A______________________ (please write your name if you do not know your A-number)

(Circle one number for each item to indicate your rating from low to high)

Rate your ANXIETY in the following situations.	**Low**				**High**
16. Using a calculator to answer a complex problem.	1	2	3	4	5
17. Thinking about a math test one day before the test.	1	2	3	4	5
18. Watching a teacher work an algebraic equation.	1	2	3	4	5
19. Taking an examination in a math course.	1	2	3	4	5
20. Being given a homework assignment with many difficult problems that is due the next class meeting.	1	2	3	4	5
21. Listening to a lecture in math class.	1	2	3	4	5
22. Listening to another student explain a math formula.	1	2	3	4	5
23. Being given a “pop” quiz in a math class.	1	2	3	4	5
24. Starting a new chapter in a math book.	1	2	3	4	5

Read each statement and rate whether you agree or disagree. (Check one response for each item to indicate your rating)	Strongly Disagree	Mostly Disagree	Mostly Agree	Strongly Agree
25. Your **math** intelligence is something very basic about you that you can’t change very much.	❑	❑	❑	❑
26. You can learn new things, but you can’t really change how intelligent you are in **math**.	❑	❑	❑	❑
27. No matter how much **math** intelligence you have, you can always change it quite a bit.	❑	❑	❑	❑
28. You can always substantially change how intelligent you are in **math**.	❑	❑	❑	❑
29. You are a certain kind of person, and there is not much that can be done to really change that.	❑	❑	❑	❑
30. No matter what kind of person you are, you can always change substantially.	❑	❑	❑	❑
31. You can do things differently, but the important parts of who you are can’t really be changed.	❑	❑	❑	❑
32. You can always change basic things about the kind of person you are.	❑	❑	❑	❑

Rate your level of agreement with each statement. (Check one box for each item to indicate your rating)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
33. Overall, I think this course has been very difficult.	❑	❑	❑	❑	❑
34. Even if I try very hard, I do not think I will do as well in math as well as I do most subjects.	❑	❑	❑	❑	❑
35. The inadequacy of a student’s math background can be overcome by good teaching.	❑	❑	❑	❑	❑
36. The low mathematics achievement of some students can generally be blamed on their teachers.	❑	❑	❑	❑	❑
37. I understand mathematics concepts well enough to do well in math.	❑	❑	❑	❑	❑

Student Number: A______________________ (please write your name if you do not know your A-number)

Rate your level of agreement with each statement.
(Check one box for each item to indicate your rating)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
38. Students' achievement in math is directly related to their teacher's effectiveness in teaching math.	❑	❑	❑	❑	❑
39. I wonder if I have the skills necessary to take math courses.	❑	❑	❑	❑	❑
40. To understand math, I sometimes think about my own experiences.	❑	❑	❑	❑	❑
41. I am good at math.	❑	❑	❑	❑	❑
42. If I work at it, I can do well in math.	❑	❑	❑	❑	❑
43. Most subjects interest me more than math.	❑	❑	❑	❑	❑
44. Math is basically a lot of facts, rules, and formulas to memorize and use.	❑	❑	❑	❑	❑
45. Good math teachers show students the exact way to answer the questions students will be tested on.	❑	❑	❑	❑	❑
46. I enjoy learning new things in math.	❑	❑	❑	❑	❑
47. Math helps me understand the world around me.	❑	❑	❑	❑	❑
48. I have had some math classes that were taught in a very interesting way.	❑	❑	❑	❑	❑
49. Many situations in the world around me can be explained using math.	❑	❑	❑	❑	❑
50. I often feel like I'm missing important skills in math class.	❑	❑	❑	❑	❑
51. I want to study more math.	❑	❑	❑	❑	❑
52. Working in groups helps me learn math.	❑	❑	❑	❑	❑
53. I rarely see situations outside of school that can be explained using math.	❑	❑	❑	❑	❑
54. I try to avoid courses that involve math.	❑	❑	❑	❑	❑
55. When I get stuck on a math problem, I can usually figure it out.	❑	❑	❑	❑	❑
56. Writing about math makes it easier to learn.	❑	❑	❑	❑	❑
57. In math, I can discover things for myself.	❑	❑	❑	❑	❑
58. After I've forgotten all the formulas or rules, I'll still be able to use ideas I've learned in math.	❑	❑	❑	❑	❑
59. I'm never sure my answer is right until I'm given the solution.	❑	❑	❑	❑	❑
60. Learning math makes me nervous.	❑	❑	❑	❑	❑
61. Doing math helps me think clearly and logically.	❑	❑	❑	❑	❑
62. I don't really understand math until I work it out for myself.	❑	❑	❑	❑	❑
63. I don't need a good understanding of math to achieve my career goals.	❑	❑	❑	❑	❑
64. Overall, I think this course was very challenging for me.	❑	❑	❑	❑	❑

Appendix B. Data Coding and Abbreviations

Data Coding

Detailed information about different variables and what they represented can be found in Table 24. The Likert scale items were coded from 1-4 or 1-5 as appropriate and then used to calculate the summary variables used in the analysis.

Dweck's mindset was abbreviated to 8 questions and a mindset was assigned to each student by the following coding scheme: To each item answered in favor of a Growth mindset +1, to each item answered in favor of a Fixed mindset -1, and 0 if the student responded in the middle (some students chose to make their own answers instead of pick one of the four options) or if an item was unanswered.

After scoring each item, the sum was calculated and mindset was assigned as follows: For a sum of 2 or more, a Growth mindset; for a sum of -2 or less, a Fixed mindset; for a sum between -2 and 2, a Neutral mindset. If a student answered fewer than 7 of the questions for mindset, we left mindset as unknown.

The same scoring method was employed on the Math Mindset items, except there were only 4 items out of the 8 items that dealt directly with students' beliefs about their mindset in math. If a student did not answer all items for math mindset, then mindset was set as unknown.

Missing values from surveys obtained were recorded as 999 when answers were expected (to questions that were considered mandatory). Blank entries represent non-participation for survey items where responses are not expected and missing values for other collected data (such as end of semester grades).

Table 24

Data Coding for Public Data Set

Variable	Label(s)	Description
Observation	Obs	Identifier for each participant, replacing identifying student ID number.
Multiplication Facts Correct	(Pre/Post)TestCor	Number of multiplication facts answered correctly by the student during the timed multiplication facts assessment.
Multiplication Facts Skipped	(Pre/Post)TestSkip	Number of multiplication facts skipped by the student during the timed multiplication facts assessment (meaning they answered multiplication facts before and after the skipped item).
Multiplication Facts Incorrect	Test Inc	Number of multiplication facts answered incorrectly by the student during the timed multiplication facts assessment.
Course Enrollment	Enrolled	Identified which course the student was enrolled in out of Math 990, Math 1010, and Math 1050 marked as “A”, “B”, and “C”, respectively.
Course Section	(Pre/Post)Section	Course section where students took the pre/post assessment.
Year of Birth	YearofBirth	Year of birth reported by the student.
Gender	Gender	Coded as “M” and “F”.
Language	Language	First language as given by the student. Data was entered as text.
Years Completed	YrComp	Number of years of school student completed prior to this math course.
Year of Last Math Class	LMwhen	Year when student took their last math class.
Last Math Class	LMwhich	Last math class taken by the student as reported by the student. Responses indicating identical classes were formatted identically.
Last Math Passed	LMpass	Categorical variable representing whether students passed the last math course they took. Entries were coded as “Y” and “N” for “yes” and “no” respectively.

Variable	Label(s)	Description
Breaks in Education	Break(A/B/C) BreakTime(A/B/C)	Breaks in education reported by the student. There were four primary responses and other responses were recorded in these entries. When students marked a response, a time was also recorded if students reported a time amount. All BreakTime entries are recorded in years. Identical responses were formatted identically.
Major	(Pre/Post)Major (Pre/Post)Major(2/3)	Entries recording student's major at the time of each survey, as reported by the student.
Preparation Items	(Pre/Post)12 thru (Pre/Post)15	Items testing student preparation and enjoyment of school and math. Items were ranked on a Likert scale and entered 1-5 with 1 being "low" and 5 being "high."
Anxiety	(Pre/Post)16 thru (Pre/Post)24	Items testing student anxiety taken from the Abbreviated Math Anxiety Scale (AMAS). Items were ranked on a Likert scale and entered 1-5 with 1 being "low" and 5 being "high."
Mindset	(Pre/Post)25 thru (Pre/Post)32	Items testing student anxiety, taken from the Abbreviated Math Anxiety Scale (AMAS). Items were ranked on a Likert scale and entered 1-4 with 1 being "Strongly Disagree" and 4 being "Strongly Agree."
Attitudes	(Pre/Post)33 thru (Pre/Post)64	Items testing student attitudes toward mathematics, taken from Dartmouth College. Items were ranked on a Likert scale and entered 1-5 with 1 being "Strongly Disagree" and 5 being "Strongly Agree."
Need Retake	NeedRetake	During the post survey, students were asked if they felt they would need to retake their math course.
Resources Used by Student	3a - 3j	Items were coded as 1-4 for the responses "Never", "Once", "Occasionally", and "Frequently", respectively. Item 3h had a fifth option, "Not Applicable because not enrolled in Math 1050", which was coded as 0.
Other Online Resources	OtherOnline	Other online resources mentioned by the student. Responses were recorded as given by the student with commas between different items.

Variable	Label(s)	Description
Attendance	Attendance	In Math 990, attendance was taken and recorded. This variable is only recorded for Math 990.
Quiz Scores	QuizScore	Quiz scores were recorded for most Math 1010 sections and all Math 1050 sections. Values were recorded in percent of possible points. A score of 0 represented non-participation.
Quizzes Completed	QuizComplete	The percent of quizzes completed by the student. Although most sections of Math 1010 had quizzes, only Math 1050 had data to indicate the percentage of quizzes that were completed by each student.
Homework Completion	HomeworkComplete	The percent of homework assignments completed by the student out of all homework assignments assigned in his/her section. Most Math 1050 students did not have homework assignments as described before.
Homework Score	HomeworkScore	The percent of possible points earned from homework assignments. Most Math 1050 students did not have homework assignments as described before.
Exam Scores	Exam1 Exam2 Exam3 Exam4 FinalExam	The percent of possible points earned from each exam. The number of exams given in each section may differ within the same course. Regressions performed for each course utilized only scores from exams that were common to all or at least a majority of students in all sections for that course.
Percent of Points Earned	Grade	The percent of points earned from the class. This value is weighted according to the syllabus for the section the student was enrolled (i.e. it is the actual percent they earned in the course).
Course Letter Grade	LetterGrade	The letter grade assigned to the student. Please note that because syllabi differ between sections and because of teacher discretion, two students with the same percent of points earned may not have received the same letter grade.

Variable	Label(s)	Description
Course Outcome (P/DFW)	Outcome	The final outcome of the student as far as pass, drop, fail, and withdrawal were concerned. A value of "D" was given to students who withdrew from the course before the drop deadline (no record of the course was placed on their transcript). A value of "W" was given to students who withdrew from the course after the drop deadline but before the withdrawal deadline (a record of the course was placed on their transcript). For all other students who did not withdraw before the withdrawal deadline, a value of "P" for pass or "F" for fail was assigned. Students were considered passing if their course letter grade was a C- or higher. All other course letter grades were considered to be failing.
Course Evaluations	IDEAscore	Score given from the semesterly IDEA course evaluations. Student scores were given based on his/her post section's IDEA score.

Table 25

Groupings for Last Math Course

Last Math Course Levels	Courses Included
0 - Math 990 or equivalent	Accounting, Algebra I, Aviation Math, BAAT Math, “Basic Math Course”, Business Math, Drugs and Dosages, Financial Algebra, High School College Math, High School Math, Intro to Math, Math 990, Math 990, Math and Personal Finance, Math for Real Life, Math for Social Science Majors, Math for the Trades, Math I, Math in the Real World, Math Studies, Math Studies II, Modern Math, Personal Finance, Personal Finance Business Math, Physics, Placement Test (for a student enrolled in Math 1010), and Pre-Algebra.
1 - Math 1010 or equivalent	Accuplacer (student enrolled in Math 1050), Advanced Functions, Advanced Math, Advanced Math Topics, Algebra II, College Algebra, College Prep, Geometry, Intermediate Algebra, Intro to College Algebra, Intro to College Math, Math 1010, Math 1030, Math III, and Senior Math.
2 - 1000 level Statistics	“1040”, Intro to Statistics, Probability and Statistics, Stat 1040, Stat 1250, and “Statistics”.
3 - Math 1050 or equivalent and high-level statistics	Math III, IB Math, Math 1050, Math 1060, Pre-calculus, Stat 2300, Stat 2200, Trigonometry.
4 - Calculus or higher	AP Calculus, Calculus, Calculus I, Calculus II, Discrete Math, Intuitive Calculus, Math 1100, and Math 1210.

Appendix C. Effect of Factors on Percent of Points Earned and Pass Rates

Table 26

Summary of Effects of Several Factors on Outcomes

		Dweck mindset			Multiplication skills		Prior math course		
Outcome	Course	Neutral	Growth	Gender	Correct	Incorrect	Per year since	Passed	HW completion
Grades	Math 990	4.91	7.17*	3.79	.10	−1.47*	.37	4.34	.79***
	Math 1010	7.99**	11.59***	2.31	.13**	−.10	1.07***	3.71*	.67***
	Math 1050	2.45	3.60*	−.62	.09*	−.58	.57	2.89	—
Pass	Math 990	−.11	.45	.51*	.01	−.14*	−.02	.67*	.10***
	Math 1010	.99**	1.10***	.12	.01	.01	.17***	.52**	.08***
	Math 1050	−.41	.11	−.20	.02	−.08	.11	.29	—

		AMAS anxiety factors				Dartmouth attitude factors		
Outcome	Course	Anxiety	LMA	MEA	Ability	Interest	Personal Growth	Utility
Grades	Math 990	−2.00	−3.10*	.14	3.05	3.29*	.51	2.07
	Math 1010	−3.39***	−3.51***	−1.98**	5.88***	3.92***	2.64**	3.37***
	Math 1050	−3.49***	−3.45***	−2.22***	5.16***	3.15***	1.40	2.02***
Pass	Math 990	−.39**	−.42**	−.15	.23	.46**	.02	.18
	Math 1010	−.40***	−.37***	−.26***	.65***	.45***	.23*	.38***
	Math 1050	−.76***	−.73***	−.44**	.99***	.48***	.33	.31*

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 27

Summary of Effects from Time Spent in Breaks in Education

Outcome	Course	Military time	Stay home time	Worked time	Rel. serv. time	Other time	Total time
Grades	Math 990	.93	−.07	.84*	−.02	−5.23	.48
	Math 1010	.31	.13	.03	2.43**	.81	.24
	Math 1050	−1.42	.17	−.04	1.06	−3.67	.04
Pass	Math 990	.07	−.09	.01	.05	.74	−.02
	Math 1010	−.03	−.04	.00	.30**	.10	.01
	Math 1050	−.01	−.08	−.09	.24	−.41	−.05

*$p < .05$, **$p < .01$.